METALLURGIA
THE BRITISH JOURNAL OF METALS.

SEPTEMBER, 1932. VOL. VI., No. 35.

Steel Furniture and Office Equipment

Steel in various forms is being increasingly used to meet present-day demands for furniture and equipment that is economical, efficient, and posesses fire-resisting qualities. The trend towards the exclusion of superfluous ornamentation has assisted its development in this field.

RAPID development has been effected during recent years in the increasing application of steel to the construction of large buildings. Not only is the main structure now mainly of steel, with a brick or stone casing, but partitions and doors are now, to a considerable extent, being made of steel. The saving of floor space obtained as a result of steel partitions is frequently an important consideration, but the reduction of fire risk by displacing wood is not by any means the least important advantage of their use. Steel partitions are now available in sections that are easily erected, and should any modification of the room area subsequently become necessary they can be dismantled and re-erected to suit the re-arrangement of room space desired. This is a distinct advantage since the readjustment can be readily effected with comparatively little delay in working arrangements.

But while the application of steel to these purposes has become apparent, the change that has been effected in the use of various forms of steel to furniture and equipment has not attracted the same attention in this country, yet its use is quite a logical step in the desire to eliminate everything combustible. In this direction there has been remarkable progress. Steel furniture can now be obtained which provides an economical method of achieving fire-proof construction. A wide range of office requisites in steel include filing and card-index cabinets, desks, tables, cupboards, wardrobes, shelving and waste-paper baskets.

The modern tendency towards the exclusion of superfluous ornamentation has assisted in the development of this type of furniture which is designed from the modern viewpoint, and in harmony with modern architectural and decorative ideas. Their clean-cut directness of design is allied with precision and soundness of construction and excellence of finish. Steel equipment is so constructed that it establishes a new standard of efficiency, and, in addition, can be given a durable finish that is pleasing and is not easily scratched or damaged in any way.

By courtesy of] [Messrs. Pels, Ltd., Oldbury.

Steel-tube furniture in use in a well-known London cafe.

Steel-tube dining-room furniture.

By courtesy of] [Messrs. Pels, Ltd., Oldbury.

Progress made in metal finish has been such that steel furniture can be made to resemble wood without the disadvantages wood possesses. In many instances, however, efforts have been made to combine steel with glass, cane, wood, leather, and cloth upholstery, as well as other material in the making of furniture, and the results give scientifically designed furniture that possesses many advantages. In these composite designs steel tubes have been applied with remarkable success. It is not necessary to emphasise how valuable to engineering is the manufacture and manipulation of metal tubes ; the great strides that have been made in this field are well illustrated by their wide application, but new uses found for them, especially in the replacement of wood, include a wide field in office and domestic furniture manufacture.

Composite chairs and stools of this character are made of steel tubing, bent in one piece, on the most ingenious lines, to form the legs, sides, back, and the complete general

framework. Any desired upholstery is then added. The tubing may be of rustless and polished chrome-steel finish or coated with cellulose paint of any required colour. Similarly, tables are formed of bent steel tubing with, say, wood or glass tops, the latter being clear, black, or any desired colour. On similar lines every description of furniture is available including desks and filing cabinets.

Apart from office, laboratory, general canteen application in industrial establishments, etc., the matter is of interest because,

By courtesy of] [*G. A. Harvey & Co. (London), Ltd.*

All steel desk.

Steel-tube office desk with three drawers and cupboard.

By courtesy of] [*Messrs. Pels, Ltd., Oldbury.*

for many purposes, the ideal arrangement for shelves and other receptacles is a framework of rustless steel tubing on these lines, in conjunction with glass or polished plastic material (synthetic resins) instead of using wood.

Furniture of this kind, although lighter than wood, is of great strength and will withstand the roughest treatment. It possesses fireproof qualities, and, because of its reduced weight, is particularly important for use on ships, motor-coaches, aeroplanes, and railway trains, while the hygienic properties make such furniture ideal for hospitals, nursing homes, and sanatoria. It has, of course, general office applications, especially when it is considered, as some do, that the all-steel construction is too "cold" to meet æsthetic tastes.

The rapidity with which steel in various forms has been applied to furniture indicates the degree of change being effected from that consisting primarily of wood, and there can be no doubt of the advantages of steel in the making of equipment suitable for factories, warehouses, hotels, etc., while steel racks, bins, lockers, and shelving serve a wide variety of uses with far greater efficiency than wood.

Rubber-lined Centrifugal Pumps

FOR the pumping of acid, corrosive, and difficult liquids containing solids, as in connection with pickling, for example, valuable is the latest design of the "Flexala" pump when non-abrasive material is concerned. Like the "Stereophagus" pump, this is the invention of the Hon. R. C. Parsons, brother of the late Sir Charles Parsons, of steam-turbine fame, and is manufactured by the Pulsometer Engineering Co., of Reading.

Essentially, the design is that of an ordinary centrifugal pump, but with the important feature that the impeller is covered with specially tough rubber. In a modified type, the cover as well as the impeller is lined in this way, while in another development, known as the "Resiline" pump, the whole of the interior of the casing is protected on these lines, and is available for use with water or other liquids containing sand and similar abrasive products.

It is well known that rubber is a peculiarly resilient and resistant material, and, for example, a prominent rubber firm in Manchester laid down a pavement in front of their offices well over half a century ago, and this is still in perfect condition, although metal, for example, would long since have been worn out. Also in this connection it may be stated that one of the earliest examples of rubber paving in London is a small area of rubber slabs, 2 in. thick, laid in 1870 at the arrival platform entrance at St. Pancras Station, while another interesting early experiment was in 1913, when part of the Borough High Street, Southwark, was laid with rubber-capped hardwood blocks. Notable also is that several hundred square yards of New Bridge Street in London were laid with rubber in 1926, and about 16,500 vehicles pass over every day. This represents an average of 266 tons per yard width per hour for the whole width, but the actual figure is about 300–320 tons, as the centre of the road, between the lines of traffic, is little used. After five years the rubber blocks showed no sign of wear, although wooden blocks have been worn down over half an inch.

Similarly, the "Resiline" pump has run continuously for comparatively lengthy periods, pumping a mixture of water and extremely hard and abrasive sand.

It is well known that crude rubber, the coagulated sap or latex of the rubber tree, is mixed with various chemicals and fillers, and then submitted to vulcanisation. Under these conditions rubber possesses anti-abrasive and shock-absorbing properties to a unique degree, while also it has a tensile strength approaching that of metal, and in addition can be varied in quality within a wide range, according to the exact method of treatment. Consequently, rubber is little affected by erosion at ordinary atmospheric temperature, and the rubber-lined centrifugal pumps are able to deal with almost every class of acid and corrosive liquid without difficulty.

Very efficient methods have now been developed of attaching rubber to cast iron, gunmetal, or other metals, and the achievement represents a great advance in the field of pumping under high-speed conditions, with resultant small capital cost, weight, and floor-space for unit duty.

The Safety of Aged Boilers

It is not justifiable to condemn boilers on the score of age alone: many failures are directly attributable to the methods employed in manufacture.

IT is commonly reported that the iron in old boilers has become brittle during service and is no longer safe. Reports of this nature are exceedingly difficult to assess at their true value, generally owing to the lack of scientific evidence. In this connection it must be remembered that boilers of over 50 years of age were built before any serious scientific supervision of the quality of the material and the workmanship was instituted, and even where such tests have been made the results are often lost, few records having been kept over such long periods. In many cases, therefore, it is impossible to decide whether defects found to-day are the result of a deterioration of the metal, or have developed slowly during the life of the plant from some fault which has existed since manufacture. A resumé of the experience of the Manchester Steam Users' Association, by Mr. V. B. Harley-Mason, in its recently published memorandum, will do much to dispel misapprehension which exists about the use of old boilers.

Many of the cases of failure which occur during service, said Mr. Harley-Mason, are due to a combination of stress or alternating stresses accompanied by corrosion. For instance, grooving at lines of flexure, such as in the roots of flanges of end-plates and furnaces, is most probably due to corrosion fatigue. A number of faults of this type can be traced to original faulty design, as in old practice flanges were commonly made with too-small a radius of curvature in the root; also insufficient allowance was made for the expansion of furnaces, etc., with the result that excessive local strains were set up. Serious stresses, due to bending, often occur at lap joints (which were so commonly used for the longitudinal, as well as the circumferential, seams of boiler shells), due to the fact that the two parts of the shell are not truly in line; these, under fluctuating conditions of steaming, often produce a repeated variation of stress over a much wider range than was realised or allowed for in design. Fatigue of the metal is thus set up and grooving occurs.

It is also well known that in fatigue tests failure is greatly accelerated if the test-piece has a nick or crack in one of the more highly stressed surfaces. Stresses become highly intensified in its immediate vicinity, and ultimate failure of the piece takes its origin therefrom. Thus, in these longitudinal lap seams regions of intensified stress were often set up by the careless use of a caulking tool.

A considerable number of cases are recorded where boiler plates have either cracked or grooved against longitudinal lap seams, and these indicate that the wrought-iron plates used long ago were very variable in quality, and even when steel plates were introduced into boiler practice in the early 'eighties their quality was also variable, and not to be compared with the steel plates used in the construction of modern boiler plant.

To understand the reason for these cracks, it must be remembered that in the manufacture of these old plates, bars and slabs of wrought iron were piled together, reheated, and rolled into plates. In piling, the bars were packed in layers, each layer crossing the adjacent ones, the top and bottom layers being covered with complete slabs of wrought iron, as it was known that joints on the outer surface did not weld satisfactorily. Reference was made to the case of a plate in which cracks were found after 75 years' service. On examination it appeared as if near the edge such uncovered joints have occurred, due probably to the covering plate in the pile being slightly on the small side. The joints may not have properly welded up, and may have formed laminations running the full length of one side of the plate, and which, during the lifetime of the boiler, have opened up slightly, causing cracks on the inner surface. In this case, although no evidence of deterioration of the metal could be found, years of service had revealed defects inherent in the plate since manufacture.

Another instance mentioned referred to a small piece of plate from a similar boiler of similar age, but somewhat different in character. The piece had fractured through three rivet holes. Fine cracks were also discovered at each of the remaining holes. The fracture was distinctly laminated, the plate appearing to be "flaking" away. The plate was of wrought iron of the usual quality, containing a considerable amount of slag. An examination showed the severe distortion of both the slag threads and the crystals of iron resulting from punching the rivet holes instead of drilling them. The metal had been stressed far beyond the yield point, and was in a suitable condition for corrosion to occur.

An examination of the cracks showed them to be of a peculiar type and quite unlike the lamination type of crack found in the previous plate. The cracks were intercrystalline in character (Fig. 7), and resembled the cracks commonly found in mild steel plates which have been subjected to the combined effects of stress and water rich in caustic soda. There was, however, no reason to suspect "caustic embrittlement" in this case, and the presence of these inter-granular cracks is difficult to account for. It is possible that they had been slowly caused by some intergranular corrosion or attack during the long life of the boiler. On the other hand, there is always the possibility of intergranular films of oxide in these old wrought irons, consequent upon their method of manufacture, which, under certain conditions of stress, cause an intergranular weakness of the metal. If this latter supposition is correct, then, here again, there is no evidence of deterioration, failure being due to faults inherent in the plate since manufacture.

Water-Tube Boilers.

As far as water-tube boilers are concerned, these, naturally, are not of the age of the old Lancashire or Cornish boilers, but, nevertheless, there are many old water-tube boilers still working where wrought iron was the material used for the tubes. In these cases it is often reported that the tube ends have become brittle with age, and this report is not by any means always restricted to wrought-iron tubes.

Of several examples of this brittleness of tube ends which have come to the notice of the Association, one of the first was a portion of one of the top row of tubes from an old water-tube boiler. This tube was reported to have become very brittle at the back end. From the analysis and the micro-examination the tube was obviously of wrought iron, the composition being as follows :—

C and Si trace; Mn, 0·03%; S, 0·02%; P, 0·07%.

The micro-examination revealed the usual grain structure and slag inclusions typical of wrought iron, but within the grains a large number of black dots and needles, which are probably oxide of iron, were found. It was also noticeable that parts of the grain boundaries were very dark, while the remaining portions had barely etched. This may be due to the presence of thin films of oxide lying between the grains. If the brittleness of the tube is due only to these films and needles, which must have been present since the manufacture, then it appears as if the tube had always been brittle and had not become brittle with age.

The presence of these needles is by no means a rare phenomenon, and in most cases where brittle tubes have been examined such needles have been found. What effect these needles have on the ductility of the iron it is difficult to say, but lying along the cleavage planes they must weaken the material. Goodger[1] states, however, that "in spite of the presence of needles in brittle welds, they do not seem to affect the fracture, which avoids them and passes always between the grains just as though there were a brittle film there." The possibility of thin ultramicroscopic films of brittle material, such as oxides or nitrides, accompanying the needles, would, however, account for the brittleness of such wrought irons. Moreover, as it is difficult to conceive these films and needles forming during the lifetime of the wrought iron, it must be assumed that they were present since manufacture.

Lap-Welded Tubes

Another point of interest which arises is due to the fact that most of these old wrought-iron and steel tubes were lap-welded. As far as the latter are concerned we have frequently found that the tubes have been overheated in the vicinity of the weld, giving rise to structures which are weak, particularly where shock is concerned. A possible or contributory cause of tube-end brittleness is work-hardening during the expanding of tubes into drums and headers. The extent of this hardening was shown in some tests which we carried out on a steel nipple and on the end of a downtake tube from a water-tube boiler. In the first place two longitudinal strips 6 in. long and ½ in. wide were cut from the nipple and the downtake tube and subjected to bend tests. In each case it was found that fractures only took place after bending through 180° to a very small radius. The material, therefore, could not be called brittle, and when examined microscopically showed a normal fine-grained mild-steel structure. There was no evidence to suggest brittleness.

Similar longitudinal sections were cut from the full length of the nipple and from the expanded end of the downtake tube, and hardness tests of the Brinell type, using a 100-kilog. load and a ⅛-in. diameter ball, were made all over the sections. The hardness results showed that severe strain-hardening had occurred in both tubes at the expanded portions, the hardness figures in these parts suggesting that the metal had been strained to near the cracking point. The body of the tubes was, however, quite soft, and it is reasonable to assume that any brittleness due to this cause will be restricted to the tube ends and, in particular, the expanded portions.

Effects of Lap-Welding and Work-Hardening on Tubes.

A further example of this tube-end brittleness, due to the effects of lap-welding, and to the work-hardening caused by the expanding, was noticed recently when a 3¼-in. dia. generating tube from a water-tube boiler fractured while the end was being re-bellmouthed. The end of the tube had fractured with a coarse brittle fracture for approximately half the circumference level with the tube-plate surface nearest the tube end. A small fracture in the tube-level with the other face of the tube-plate appeared to be due to a hammer blow and exhibited a similar type of fracture. Rings cut from other portions of the tube appeared in good condition, as sections cut from them and used as bend tests showed that the brittleness was restricted to the tube ends.

A micro-examination showed the structure to be coarse-grained and angular, the pearlite having a decided tendency to lie along the grain boundaries. This structure is weak where shock is concerned, and is due to the overheating of the tube during the lap welding. Hardness tests carried out on sections showed, as in the case of the nipple and the downtake tube just referred to, that considerable work-hardening had occurred during the expanding of the tube into the drum. The brittleness in this case was doubtless due to the combined effect of the work-hardening of the steel in the vicinity of the expanding and the weak structure due to the overheating during welding. It is possible that during the long period at which the tube is subjected to temperatures between 200° and 250° C., a certain amount of embrittlement of the overstressed parts may develop, and the bellmouthing, putting a severe stress on the edge of the expanded portion (a stress concentrated by slight grooving or "necking"), revealed the weakness of the structure and caused the brittle fracture.

[1]The Institution of Welding Engineers, 1927.

Forthcoming Meetings

THE IRON AND STEEL INSTITUTE.

BIRMINGHAM.

Sept. 29. Joint meeting with Staffordshire Iron and Steel Institute, the Coventry Engineering Society and the Coventry and Birmingham Centres of the Institution of Automobile Engineers at the University. Papers to be discussed include:—"Metallurgical Problems Arising from Internal-combustion Engine Valves," by J. R. Handforth; "Fatigue Resistance of Unmachined Forged Steels," by G. A. Hankins and M. L. Becker; and "Nickel-chromium-silicon Cast Irons," by A. L. Norbury and E. Morgan.

MIDDLESBROUGH.

Oct. 3. Jointly with the Cleveland Institution of Engineers at the Cleveland Technical Institute. "Metallurgical Problems Arising from Internal-combustion-engine Valves," by J. R. Hanforth; and "Generation of Steam from Blast-furnace Gas," by A. F. Webber.

MANCHESTER.

Oct. 5. Jointly with the Manchester Metallurgical Society at the Engineers' Club. "The Endurance Limit of a 0·33% Carbon Steel at Elevated Temperatures," by J. W. Cuthbertson; "Metallurgical Problems Arising from Internal-combustion Engine Valves," by J. R. Handforth.

SHEFFIELD.

Oct. 11. Jointly with the Sheffield Metallurgical Association at the Sheffield Metallurgical Club. "Fatigue Resistance of Unmachined Forged Steels," by G. A. Hankins and M. L. Becker; "Spectroscopic Estimation of Nickel, Manganese, and Chromium in Steels," by F. Twyman, F.R.S., and A. Harvey; and "Scale Removal by Acid Pickling," by A. B. Winterbottom and J. P. Reed.

SCUNTHORPE.

Oct. 11. Jointly with the Lincolnshire Iron and Steel Institute at the Central Schools. "Blast-furnace Engineering," by W. R. Brown; "Improvements in the Greenawalt Sintering Apparatus," by J. Tornblad; "Generation of Steam from Blast-furnace Gas," by A. F. Webber.

THE INSTITUTE OF MARINE ENGINEERS.

Oct. 11. "A New High-speed Marine Diesel Engine," by A. F. Evans.

INSTITUTE OF METALS.

Oct. —. Jointly with the Manchester Metallurgical Society, to discuss certain papers included in the autumn meeting programme.

SCOTTISH SECTION.

Oct. 10. Chairman's Address, by Professor Robert Hay, Ph.D.

SWANSEA.

Oct. 11. "Refractory Materials and the Non-ferrous Industries," by Alfred B. Searle.

NORTH-EAST COAST.

Oct. 11. Chairman's Address, by A. Logan.

BIRMINGHAM.

Oct. 13. Symposium on Hardness Testing.

LONDON.

Oct. 13. Chairman's Address, by S. L. Archbutt.

SHEFFIELD.

Oct. 14. Chairman's Address on "Annealing," by Capt. F. Orme, M.Met.

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Contributions suitable for the editorial pages are invited. Photographs and drawings suitable for reproduction are welcome. Contributions are paid for at the usual rates.

PRINCIPAL CONTENTS IN THIS ISSUE:

Subscription Rates throughout the World - - 24/- per annum, Post free.

Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at 21, Albion Street, Gaythorn, Manchester.

Telegrams: "*Kenpred,*" *Manchester.* *Telephone: Central* 0098.

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Is Trade on the Turn?

IT is significant that there has been a steady improvement in security prices of late which has gradually spread to most of the stock exchanges of the world, and it is of interest to note that this improvement has been accompanied by a similar movement in the price of several important commodities. Can we take an optimistic view of these movements and believe that they represent a silver lining to a very black depression cloud that will gradually bring about its dissemination, or is it merely a delusion that will pass and leave the outlook blacker than ever? The question is of vital importance to us all, but he would be a rash man who would venture a positive answer, although his hopes were well defined.

There can be no doubt that the outlook is a little brighter, but there is no indication as yet that it has had any effect on employment, production, or trade; certainly statistics do not show any appreciable signs of economic activity. At the end of August the unemployment figure was the highest ever recorded at this time of the year, and was very near the three-million mark. The figure was actually 48,000 more than during July, and 126 000 more than during August of last year. The Board of Trade returns for August also indicate the extent of the damage being done by the economic war between Britain and the Irish Free State. An enormous contraction of trade has taken place in the five months since Britain's general tariff system began to operate. As compared with the same period last year imports are down by £71,639,600, and exports by £6,650,500.

But although the cloud has not dispersed, this does not necessarily prove that the prospects are not improving; frequently it is some time after a brighter gleam is visible in the sky that we experience the benefits, and there must inevitably be some delay before industrial improvement shows itself in the form of statistics. Some people assert that the improvement that has taken place in industrial stocks and in wholesale prices may be due to a recovery from the absurdly low level brought about by the almost bankrupt condition of many countries. The fear of bank failures is not now so prevalent in various countries, and money that has been hoarded is being brought out and invested.

The steady improvement experienced does not justify a feeling of ecstacy, for it is a very modest one, and could quite well be continued without bringing about anything approaching a spectacular recovery. At the same time the rise in securities has relieved many financial institutions from a situation of acute difficulty and made the position of banks more liquid. Of more vital importance is the fact that the rise in commodities has relieved the position of farmers and producers of raw material in many parts of the world. Many of them can, at present prices, just meet their expenses instead of being faced with actual losses. At the same time there is too great a disparity between retail prices and wholesale prices, which constitutes a very important problem. If this gap could be reduced and a fairly close relationship established an immense help would be given towards facilitating production and distribution.

There is, however, little likelihood of a setback in commodity prices, for the production of many of the chief raw materials of the world now practically balances consumption. Stocks of these products have in consequence ceased to rise, and if things go well will fall as soon as merchants and manufacturers begin to distribute their circulating supplies. This will be possible through money being available on favourable terms, while low interest charges will encourage business people to undertake developments that have been postponed. The belief that prices have touched bottom will encourage them to do so now.

Whether the present position is an indication of a definite recovery is very difficult to say, but, so far as the most important economic conditions are concerned, the world certainly seems to be on the verge of a recovery. It is, however, questionable whether much improvement can be made while present political uncertainties remain. The question of war debts is still unsolved, and it is very unlikely that this will be discussed at the proposed World Economic Conference. As a matter of fact the conditions stipulated by the United States excluded the subjects of tariffs, reparations, and war debts from the Conference agenda, but it was fully expected that some discussion would be bound to take place amongst the delegates. The position is much more difficult in view of the Presidential election in November, because to tackle the question before November would undoubtedly embarrass President Hoover. Yet it was agreed at Lausanne to waive the right to collect reparations from Germany on the express condition that the United States would do the same as regards war debts due to her from European countries, and, unless the question is tackled before the next instalments become due, the position will be very embarrassing for Britain, France, and the other countries involved. These problems involve the position to such an extent that unless they are adequately solved an industrial revival of any appreciable magnitude cannot be seriously contemplated.

Other factors which will have an influence on any movement towards recovery are tariffs, exchange restrictions, and other obstructions which hinder normal trade. A glorious opportunity has been lost at Ottawa. At this conference our delegation tried to lay the foundation of an economy policy for the Empire that would ensure, both now and in the future, an increasing volume of Empire trade, brought about, as far as possible, by the lowering of trade barriers between the several members of the Empire. Although it is claimed that agreements have been made on this basis, a direct attack upon tariff barriers was a vital factor in the deliberations, the success of which would have had a considerable influence in freeing the world from the paralysing effect of economic isolation. To have given a lead to the world on tariffs would have been a valuable aid to world recovery.

It should not be assumed that the result of this conference was a failure, for it has apparently influenced Denmark and France. Great Britain provides a valuable market which these countries are not slow to appreciate. Last year, for instance, 67% of the total Danish exports were taken by this country, and the political and economic thought in Denmark is now being directed towards some arrangement whereby trade can be reciprocated. The future of Franco-British trade relations has also become a question of immediate importance since the conclusion of the Ottawa Conference, and it is urged that a new trade agreement is now due in order to restore economic prosperity.

The change in economic conditions can undoubtedly bring about a partial recovery, and under favourable conditions would probably gain momentum, but several problems of major importance must be solved to create favourable conditions, the solution of which is in the hands of politicians rather than industrialists.

Basic Principles of Selection of Furnaces.

By R. J. SARJANT, M.Sc., A.R.C.S.

The selection of the most suitable type of furnace for a given operation depends upon many factors, but the value of the result desired is of primary importance in arriving at a decision. The cost of the heating medium employed, temperature control, and other phases in heating operations are really incidental to the main consideration which involves the quality of the finished product and its overall cost. In other words, in any selection it is important to bear in mind the need for producing a high-grade product at low cost, using that form of heating medium and that type of equipment which will give these results under the particular conditions that operate in the works at which the installation is contemplated. Selection is frequently a compromise between that which is considered to be best in theory and that which, when viewed with the conditions of the particular case, is practical; each must be considered on its merits, and the following factors must be considered.

The Adaptability Value of a Fuel.—It is practicable within certain limits to use any fuel for any given operation. The choice of the fuel is usually limited by its availability and economic value, together with an assessment of certain other factors associated primarily with the use to which the furnace is to be put, and which may be classed together under a generic term, proposed by the author to be called the adaptability value of the fuel.

The first function of a furnace is to give a satisfactory product, as to degree and uniformity of heating, consistent with possibly wide variations of output and conditions imposed by the shop requirements. In this respect, if a valuable product is being heated in its final stages of manufacture—for example, a valuable forging, costly ornamental enamelled ware, or accurately finished machined parts to be subjected to a final carburisation or heat-treatment—then there is a standard of accuracy of temperature and uniformity, a degree of reliability and ease of control, that may not be attainable except with the most refined and elaborate methods. The actual cost of the heat units utilised in the furnace is a matter secondary to the essential needs of attaining the required standard of quality of product, since cost of failure far outweighs the small increment of cost in the actual energy applied, and the capital charges involved in more complicated plant. In such cases, producer gas, oil, town's gas, and electricity are strongly competitive with solid fuel.

Again, under this heading are comprised items such as floor space required for the furnace, fuel storage and supply, labour requirements, regularity and reliability of the fuel supply, and suitability for intermittent operation.

In assessing the relative importance of these various items, local conditions must naturally play a large part, but generally the dominant guiding principles emerge as follows :—

Reliability and Flexibility of Output.—With the tendency towards mass production in many industries the duty demanded of the furnace units may amount to a very precise and clearly defined treatment and output, even in the case of melting furnaces. The allowable margin to cover contingencies and unknown factors must necessarily decrease as the science of furnace heating progresses. Nevertheless, due more often to unforeseen developments of trade—an agent in this respect being the progress of engineering science—a fair measure of flexibility of output and range of temperature is demanded in many types of general heating plant. One of the modern problems of the construction of such plant is concerned with the utilisation of a wider range of permissible fuels. Many types of gas producers give excellent results with selected fuels of particular size and coking characters. The gas machine is generally claimed to operate on low-grade fuel, at high rates of gasification consistent with a low cost of labour for operation. But there is frequently encountered the objection to small, caking, and dusty coals, owing to choked flues and poorer gas. The condition of reliability should entail suitability for use with a wide range of fuels. In the case of oil, reliability may be seriously interfered with by the failure of supply due to inadequate provision against choking of feed lines in cold weather.

Mechanical Stability; Ease of Control.—In this respect there must usually be a compromise between an installation so far mechanically controlled as to be "foolproof" in operation and a mechanism so complicated as to require special handling and heavy maintenance charges. Generally, as regards these considerations, the competitive fuels—oil, gas, and electricity—have a distinct advantage over coal, for the use of the former may be readily made automatic as regards temperature control. The modern thermo-electric pyrometer is made in a robust and reliable form to work through a relay to operate either the fuel valve and dampers or the power circuit. Oil-fired furnaces are at times expensive in refractories, due to the severe erosion associated with the high-temperature flame carried. Special provision may become necessary: the use of carborundum or sillimanite, grog firebricks high in alumina, or patchings of a plastic cement milled from a mixture of silica and fireclay. Gas furnaces, particularly those using town's gas, are especially advantageous both for their mechanical stability and ease of control. This character applies with greater force in the case of small furnaces, for which coal in most respects is entirely unsuitable.

In the case of the larger furnaces, particularly continuous furnaces for rolling-mills and forges, the burner problem in the case of gas firing is not so simple, though both in this country and abroad there are such furnaces operating with perfect satisfaction in this respect. The disability lies in the burning of the nose of the burner, and may require either water cooling or some complication of design to overcome the tendency. As regards scaling and uniformity of heating, the advantage lies distinctly with coal-firing, where the combustion problems of coal-firing have been successfully handled. This applies in the case of mechanical stoking. A considerable number of large furnaces of this class are being converted to mechanical stoking. On economical grounds the mechanically fired coal-burning furnace can meet the competition of any other form of firing. Even furnaces fired by producer gas have been converted with advantage to mechanical stoking, where two-shift operation has been in practice. In such cases the stand-by losses are heavy on gas producers, particularly the separate static unit. The flame from coal is particularly favoured in the iron and steel industry. It is long, and accordingly the intensity of heating is not excessive. Also, in the absence of inordinate quantities of excess air, the rate of scaling is advantageous in comparison with fuels carrying a high proportion of water vapour. For this reason, in the case of heating special steels for rolling, the so-called green fire is still retained after much experiment with alternative fuels. It has been shown by fundamental research that the products of combustion—carbon dioxide and water vapour—are strongly oxidising agents in metal heating at high temperatures, and that the point at which there is neither carburisation by contact with combustible, nor oxidation, demands a particular set of conditions like the triple point of ice, liquid, and water vapour, and is very difficult to retain in the practical conditions of industrial heating. Actually, the composition of the gases rising from the green fuel of these furnaces gives the nearest readily practicable approach to a neutral mixture that is obtained in industrial furnaces.

The Real Problem in Industrial Rationalisation

The financial fusing of companies or firms under the guidance of lawyers and accountants is simple compared with the practical fusion of human beings who earn their living in the various component parts of the combine.

VARIOUS methods adopted in combining the component parts of large companies were referred to by Commander C. W. Craven, O.B.E., managing director of Messrs. Vickers, Ltd., in his presidential address before the Institute of Marine Engineers on September 13. He instanced the horizontal trust, which is the wedding of like with like. Followed to its logical conclusion such a scheme would mean, for example, one huge group of shipyards in the country with no competition except from foreign shipyards. This system has the tremendous advantage that, in times of depression, sections of the industry can be temporarily closed, and with improved business a nucleus of staff can be immediately supplied from those shipyards or works that are in operation. Commander Craven is of the opinion, however, that a huge combine of this kind would be difficult to control, and would breed inefficiency in its management.

Another line of thought prefers the vertical trust, where a given concern manufactures all its products from the raw material to the finished article. Both systems have their difficulties, and after some experience of them Commander Craven takes the view that neither is absolutely right or wrong, but that what is desirable for all practical purposes is a combination of both.

An organisation comprised of a horizontal group of, say, steel companies feeding, in addition to the outside market, a group of shipyards and engineering works provides an ideal combination. In bad times there is always a possibility of another outlet for the products of the steelworks, with such an organisation, and if times are bad in both groups the organisation should be flexible enough to permit of some of the works being temporarily closed and the work available concentrated in those works which are kept in operation.

Much has been said and written about the rationalisation of industry, but whatever views should eventually prevail success or failure of any scheme depends on the personal qualities of those who have to put it into operation. Whatever the industry, and whatever the form of grouping, the financial fusion of the companies or firms under the professional guidance of lawyers and accountants is a very simple thing indeed compared with the practical fusion of human beings who earn their living in the various component parts of the combine. Many human problems must be faced which require considerable care for their solution.

No hard and fast rule can be laid down regarding the number of workers for whom one man should be responsible to a board of directors. The only possible hope for success lies in putting responsibility only on those able to bear it. Whatever may be the type of product, whatever the size of the undertaking, or the nature of an appointment under consideration, the vitally important qualification for a post of great responsibility is strength of character. Every appointment of a person who has never previously had to carry heavy responsibility is in the nature of an experiment, and should a mistake be made the responsibility probably rests with those who appointed someone who was not qualified for the position.

In comparison with the old family concern of the last century, one of the dangers of a large combine is that those at the head of affairs may not keep in sufficiently close contact with the general body of their employees. Under such conditions success, if possible, is more difficult to achieve.

Where rationalisation takes the form of a holding company, with various subsidiaries, each controlled by an independent board, there is a tendency for the directors of the holding company, who really are responsible to the shareholders for the management of the group as a whole, to hesitate to interfere sufficiently on particular questions of policy, and, instead of directing the boards of the subsidiary companies, to be led to a certain extent by them. The result may be that decisions are taken favourable to one company, but contrary to the interests of the group as a whole.

There is no advantage in the amalgamation of industrial undertakings, even although engaged in the production of the same type of article, unless as a result savings can be effected and economies made, and even where these conditions operate, unless care is exercised in the selection of the personnel of the individual units, which form part of the rationalised undertaking, there is a risk that the goodwill of one or the other may be entirely lost and the amalgamated concern left with surplus buildings and plant, involving heavy oncost charges without any increase in turnover over which such oncost can be spread.

In theory both capital and labour should benefit by proper rationalisation of competing undertakings, where economies can be effected by the fusion of manufacturing interests and reduction in administrative and selling expenses, but danger lies ahead unless those responsible for putting the rationalisation into practice look farther than the paper estimates of savings which can be made. The man who has run a small business successfully, even possessing the highest technical qualifications, may not be gifted with that spirit of leadership which enables him to get that teamwork out of his subordinates without which success cannot be achieved. In this connection Commander Craven sees no hope for the future of an industry if it relies on the committee form of administration. The chairman and board of directors must, of course, be supreme in all matters affecting the policy of large undertakings, but in all matters concerning technique, production, costs, selling, and general administration, the responsibility should be placed by the board on the shoulders of the managing directors of the various constituent companies which comprise the group. The managing director, in turn, must delegate power and responsibilities to the general managers of the individual units of his company.

It must be remembered that all business started on an individual basis, and the chief of each concern took full responsibility and followed out a definite line of policy. We have now reached the days of amalgamations of interests, and if this is to mean that each unit of a group follows out its own line of policy, then we sacrifice the one principle essential to success. In the type of administration discussed, Commander Craven considers that there is a possibility of retaining much of the close personal contact and unity of purpose so successful when firms were of much smaller dimensions than they are to-day.

The Use of Coal in the Melting and Heating of Metals

By R. J. Sarjant, M.Sc., A.R.C.Sc., D.I.C.

The selection of the most suitable heating medium for various industrial operations is frequently a very real problem, in the solution of which the quality and overall cost of the finished product are of primary importance. This article is the first of a series to be published dealing with various fuels and electricity in metallurgical heating operations.

IN any discussion of the scientific uses of coal, the subject matter frequently turns on those applications of coal which involve some form of treatment producing ultimately either coke, gas, or oil, together with a whole range of valuable and important products which have formed the bases of many productive industries. If analysis is made, however, of the actual figures of the utilisation of fuel, one is forced to the conclusion that a considerable quantity of coal continues to be burnt in this country in the solid form.

In 1913 an estimate for the second Royal Commission on Coal Supplies revealed the following analysis of the uses of coal in the United Kingdom.

TABLE I.

	Million Tons.
Mines and factories	80·0
Metal industries	32·0
Ceramic and chemical industries	6·0
Gas industry	18·0
Railways	15·0
Coasting vessels	2·0
Domestic	36·0
Power plant	80·0
	269·0

Due to changes in the industrial situation, an analysis of which is complicated; though not altogether beside our subject, the home demand has shrunk. In the metallurgical industries, largely owing to the condition of the iron and steel trades, the consumption had shrunk by 8,000,000 tons in 1929. Domestic coal had fallen 10,000,000 tons. On the other hand, statistics show that the consumption of coal in the gas industry is being maintained, and there is a steady increase in the use of gas for industrial purposes. The use of electricity is rapidly growing for purposes of metal heating, but statistics of the relative proportion of heating carried out in the metal industries by solid fuels, oil, gas, and electricity are not available. Tendencies are always moving towards refinement of control—that is to say, displacement of the former by the latter method of heating,—but changes must necessarily be slow. The essential point of our argument is that a considerable quantity of solid fuel is likely to be used for some time yet in industrial furnaces. Further, solid fuel, properly used, is a cheap and efficient fuel.

An important factor in the case is the actual cost of the potential heat available in the fuel. In Table II, are detailed some characters of solid fuel which must be considered in comparing coal with other fuels for furnace purposes.

Characters of Coal from the Aspect of its Use as a Furnace Fuel.

During recent years a tremendous amount of research has been carried out in attempts to elucidate the physical and chemical nature of coal. These studies have generally been associated with its behaviour as a subject for carbonisation. Since the process of coking is carried on in the distillation zone of any bed of burning coal, either in the gas producer or on the normal fire-grate, the nature of the coal in this respect must be of consequence in contributing to the manner in which the gases are distributed through the fuel bed, and accordingly in the character of the main combustion process.

Composition and Heating Value.—In assessing the relative importance of the various determinations that may be made in an analytical survey of a coal, the heating or calorific value must be regarded as most important. It is also desirable to know the moisture content, and percentage of ash. From these it is possible to derive the calorific value of the dry ashless coal substance, which has characteristic values for particular classes of coal, especially in the case of coals from distinct areas and coalfields. In regard to this subject, reference should be made to a paper of outstanding interest, based on the presidential address to the South Wales Institute of Engineers on January 21, 1931, by C. A. Seyler, summarised in the *Journal of the Institute of Fuel*, August, 1931, p. 451. In putting forward proposals for a classification of coal, Seyler has compiled into one chart a valuable collection of combustion characters, correlated with the composition of the coal. Charts have been proposed previously by several writers correlating combustion characters with fundamental composition both as regards calorific value and chemical constituents in the case of related types, such, for example, as bituminous coals of particular ranges of calorific value. A typical chart is shown in Fig. 1. On the other hand, the Seyler chart covers the whole range of coal composition, and the correlation is extended to cover flame intensity and calorific value as well as the amount of the products of combustion and the theoretical air required.

TABLE II.

COMPARATIVE FUEL VALUES.

Fuel.	Calorific Value Gross B.th.u./lb.	Comparable Cost, Shillings per ton	Thousand B.th.u. per 1d.	Equivalent Bulk, Cub. ft./therm.	Volume of Free Air Required in Combustion for Liberation of 1,000 B.th.u.
COAL—					
Hards	13,500	19	133	0·157	11·0
Nuts, doubles	13,000	16	152	0·154	
,, singles	12,500	14·5	161	—	
Slack	11,500	12	179	—	
,, Inferior Grades	10,500	9	218	—	
COKE—					
Foundry	13,400	30	84	0·217	10·3
Furnace	12,900	15	162	0·24	10·5
Gas coke	12,900	30	80	0·276	10·4
FUEL OIL—					
Diesel	19,400	78	47	0·093	9·45
Crude	19,400	65	56		
Town's gas	500 cu/ft.	2·4d./therm	42	200	8·3
Producer gas	165	1·4d./therm	71	600	7·6

A chemical analysis of the coal is always desirable, but the full ultimate analysis of carbon, hydrogen, nitrogen, sulphur, and oxygen is not generally essential as a means of normal control of fuel supplies. It plays a more important function in research work associated with the studies of the fundamental character of coal. In this last respect much attention has been devoted to microscopical examination, and even the use of X-rays. The main utility of the former method has been to assist in the correlation of coal seams, and the latter has a value in providing a rapid means of determining the distribution, nature, and amount of the ash in coal.

For general control purposes the essential analytical

data required, besides the calorific value, is the moisture content—for obvious reasons, the ash content, and in certain uses the proportion of fixed carbon, obtained from a determination of the volatile content, a test which incidentally reveals valuable information as regards coking characters discussed later. The calorific value of the dry ashless coal substance is a valuable criterion of the class characteristics of the coal.

For furnace purposes knowledge of the nitrogen and oxygen is of small account, but in the case of sulphur knowledge of the content of this undesirable constituent is generally necessary in metallurgical practice. Sulphur is present both as organic and inorganic forms. Combined in the former it has frequently a characteristic value, and may occur to a higher degree in caking coals. Sulphur in mineral form nay be present in widely differing degree, even in the same type of coal. Both pyrites and gypsum are undesirable impurities, and they are removable, within certain limits, in the cleaning operation. Accordingly, a knowledge of the sulphur content, judged in conjunction with that of the ash content, gives a valuable analytical indication of the cleanliness of the coal. Sulphur also has well-known disabilities in metal heating, 1·5—2% being regarded as limiting maxima, for example, in the case of heating alloy steels. Above all, the matter of sampling is an important consideration. The subject has recently been receiving the attention of the British Engineering Standards Association, and certain specifications have been published.

Behaviour on Heating.—The combustion processes on any grate, whether the coal is only partially burnt or gasified, or whether the combustion is completed on the grate, are essentially the same, and only differ in regard to the oxygen content of the gases arising from the fuel bed. In the first few inches of the fuel bed the oxygen is rapidly used up, giving rise mainly to carbon dioxide. At the point of the exhaustion of the free oxygen the content of carbon dioxide is 12%, and there is a variable proportion of carbon monoxide and other combustible gases according to the rate of flow of the gases, the nature of the fuel, and the temperature of the fuel bed. Beyond this range reduction of the carbon dioxide may be commenced in thick fuel beds (gas producers). Above this zone is the portion of the fuel bed in which distillation of the volatile matter is co-curring. There must occur coking of the fuel, and the nature of this coke largely governs the character of the flow of the gases through the fuel bed. Coals which fuse and swell up choke the bed by agglutination. The gases are confined to fewer passages in the fuel bed. Channelling occurs with unsatisfactory quality in the case of producer gas, and related troubles with normal grate firing. Accordingly, therefore, a coking test is a highly desirable test.

Clinkering Properties.—The fusibility of the ash is an essential characteristic of a fuel so far as regards satisfactory combustion with low loss of combustible matter in the ash. A coal high in calorific value is not necessarily more economical than one lower in heating value but superior as regards the character of the ash. A clinkering ash chokes the lower passages of the fire-grate, and produces channels which give local hot spots which in turn aggravate the disturbance. Clinkering qualities are, of course, preferably determined from experimental determinations of the refractoriness of the ash, due allowance being made for the character of the atmosphere. A reducing atmosphere gives the most valuable indication of the behaviour in a grate, and generally the fusibility in the case of the presence of iron oxides is considerably lowered in a reducing atmosphere. Even such information must be used with due consideration of the banded constituents of the fuel and the distribution of the deleterious mineral matter in the fuel. Coal ash is essentially an aluminium silicate, resembling in type refractory fireclay, and the chief constituents producing a low fusibility arise from mineral impurities of the fuel, such as pyrites, gypsum, carbonates, and alkali salts.

The results in Table III. were published in the "Fuel Research Technical Paper" No. 23, D.S.I.R., 1929, by J. G. King, A. Blackie, and J. O'N. Millott. They are a few selected results showing a range of results for British coals. The fusion point given is a mean between results obtained by the author and the U.S. Bureau of Mines, in a mildly reducing atmosphere.

Clinkering may be reduced by water or steam addition with blast, on large grates. In the case of small grates high rates of combustion are better than low rates if there is likely to be channelling producing local beds of slow-burning coke at the points where the cooling action of the air is absent.

TABLE III.

Fusion Points of Coal Ash.

Coal.	Moisture.	Volatile Matter, Less Moisture.	Ash.	Fusion Points of Ash °C.	
				Initial Deformation.	Fusion.
1. Ravine Seam, Lancashire (bituminous caking)	2·7	34·8	11·2	1,125	1,170
2. Arley Seam, Lancashire (strongly caking)....	1·4	35·4	4·8	1,120	1,165
3. Mitchell Main, Yorkshire (Parkgate Seam)	1·0	32·7	4·8	1,250	1,385
4. Dalton Main, Yorkshire (Hards from Barnsley Seam)	3·4	32·8	4·1	1,420*	1,585*
5. Stone Coal, Thick Seam, Staffordshire	6·7	32·1	22·5	1,550*	1,600*

(* U.S. Bureau of Mines Values.)

COMPOSITION OF COAL ASHES.

Coal.	SiO_2.	TiO_2.	Al_2O_3.	Fe_3O_2.	MnO.	CaO.	MgO.	K_2O.	Na_2O.	SO_3.
1	27·1	0·86	23·16	29·24	0·10	7·09	2·73	1·47	1·71	7·35
2	24·46	0·86	19·02	27·46	0·23	9·39	4·70	1·84	1·02	10·77
3	42·86	1·55	31·63	16·16	Tr.	4·05	0·85	0·32	1·70	1·26
4	49·16	1·21	35·94	3·50	0·01	2·72	0·75	1·24	3·76	2·10
5	47·32	1·27	38·22	1·01	Tr.	6·29	0·78	0·89	0·39	3·63

Coal in Furnace Operation.

Melting Furnaces.—Coal fired on grates is used in air furnaces for the production of chilled iron castings, in which it is desired to combine a low silicon content with an absence of excessive sulphur. The fire is usually hand-operated, and the fuel bed is kept thick, to ensure the condition of high proportion of unburnt volatile combustible in the gases passing through the furnace. This class of practice has been common also in the production of malleable iron and wrought iron.

In the melting of metals the firing of solid fuel has certain disadvantages. In the case of hand firing the introduction of cold air when feeding green fuel results in heavy wear on refractories, due to spalling. The use of mechanical stoking is also not favourable because of the action of the intense heat which is bound to be radiated on to the stoker mechanism. Powdered coal has been successfully used, for in this class the high intensity of heating produced by pulverised coal has a distinct service in maintaining a high bath temperature.

A most instructive comparison of the use of solid fuel, powdered coal, oil, and gaseous fuel has recently been made in the case of copper-smelting furnaces taking charges of about 250 tons. E. S. Bardwell (Amer. Inst. of Mining and Metall. Eng. Tech. Pub'n., No. 457), has described the succession of experiences at Great Falls, Montana, with these fuels. Fire-grates, 10 ft. × 12 ft. were originally used, certainly a formidable size for firing lump coal in high-temperature metallurgical furnaces, and the coal having from 5 to 19% ash and calorific value, approximately from 10,000 to 13,000 B.th.u. per lb. The cleaning of the grates was a source of trouble, giving rise to high repair costs due to spalling of refractories. The use of pulverised coal reduced the consumption of heat per lb. of copper from 3,225 to 1,867 B.th.u. Subsequently, in succession, oil and natural gas became available under

favourable economic conditions, and the result was for comparable furnaces, as shown in Table IV. Taking into consideration the analysis and temperature of the flue gases in each case, if 46·7% of the heat units developed on combustion of the powdered coal is available for furnace work, then corresponding values of the available heat under the same conditions for oil and natural gas are 44·7 and 41·9%.

TABLE IV.

	Pulverised Coal.	Oil.	Natural Gas.
Heating value, B.th.u. per lb.	11,960	19,224	983 B.th.u. per cub. ft.
Average production, tons per charge	235	233	233
B.th.u. per lb. of copper produced	1,627	1,441	1,670

In each case the average temperature of the gases leaving the furnace was 1,940° F., and the stack temperature 600° F.

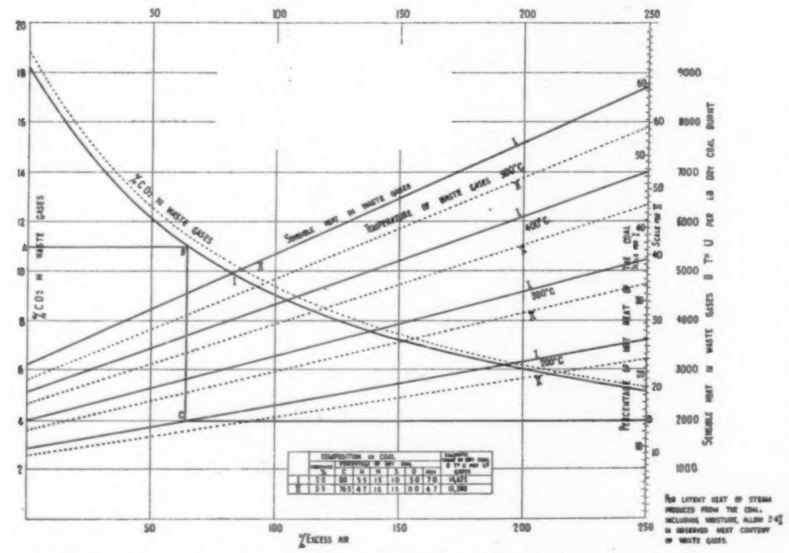


Fig. 1.—Combustion of coal. The combustion characters for the coals cited will be found to be very close. The use of the chart is indicated by the line A, B, C, D.

Reverting to the consideration of solid fuel in comparison with pulverised coal, in the case of British coals rather a different set of circumstances obtains. Many British coals are remarkably pure, free burning, readily available, and of high grade. They are generally burnt on grates, either by mechanical stoking or hand-firing, without extreme difficulty, there being available in most parts of the country operative skill of a high standard in the workmen. Further, these same coals are frequently hard, and the costs of pulverisation accordingly increased. Again, the industrial districts are densely populated, and the avoidance of ash emission from stacks introduces a complication of plant for cleaning purposes. These are some of the factors which have operated towards limiting the development of pulverised coal for metallurgical purposes.

Reheating Furnaces.—The manner of utilisation of fuel for reheating furnaces suggests a classification based on the following: (i) Large continuous furnaces for rolling mills and forges; (ii) intermittent forge and mill furnaces; (iii) small furnaces, having hearth area less than 50 sq. ft. In the case of the first class, generally in the heavy trades, solid fuel is in competition with producer gas and coke-oven gas. In the case of large units having either central producer-gas generators, or a surplus of coke-oven gas available at a price of about 6d. per thousand cubic feet, the gaseous fuels prove frequently the most economical provision. In the case, however, of isolated units, there is no doubt that mechanically-fired furnaces, capable of operating on comparatively low-grade fuels, are the most economical. Producer gas in large central units can generally be generated at a cost of 1·2d.–1·5d. per therm, available at the furnace. In small units the cost may go up to even 2·0d. per therm. In the case of coal, however, the equivalent cost is under 1d. per therm. For intermittent forge and mill furnaces, particularly in those cases in which the furnace must be cooled down to take the charge, the use of solid fuel, fired by hand, is preferable. Means have been found whereby control of combustion to give adequate heating and smokeless operation is made possible. The importance of considering the heat storage loss in the furnace structure has been indicated in a recent paper read before the Ceramic Society (Trans. XXXI., 82, March, 1932) by the author, in which an experimental investigation into the flow of heat into furnaces under industrial conditions is detailed. The losses may be so considerable as to make it necessary to use that fuel which develops its available heat units at the lowest possible price. Reference to the small furnace concerns not only the processes of reheating, but an extremely wide range of other uses.

Heat-treatment Furnaces.—This class of furnace, in the case of the smaller sizes, is almost entirely operated by those fuels competitive with coal which have a high adaptability value, as explained earlier. In the case of town's gas alone, on the authority of data supplied by the British Commercial Gas Association, there are 3,000 distinct trades using this type of gaseous fuel for industrial heating, in each of which it is employed on the average for seven processes. The large furnace is, however, conveniently heated by means of coal, either on grates, or in gas producers, as well as by coke-oven gas.

The continuous heat-treatment furnace in its most modern form for the annealing of sheets is preferably fired by producer gas, the sheets being carried forward by a conveyer made of heat-resisting metals. The principle of the reversing regenerative furnace, operating on producer gas, and preferably with the air only regenerated, is applied very successfully to batch furnaces, both of the solid bottom and car type. The recuperative furnace—that is to say, the type in which the heat exchange from the waste gases to the air takes place under continuous flow—is applicable to the batch or continuous type of heat-treatment furnace, for enamelling, carburising, and other operations carried out at one particular temperature. In this form the built-in producer is particularly successful. This type is in general unsuitable for batch working, in which the furnace has to be cooled down for the admission of the charge. The most economical furnace for such use is the coal-fired furnace.

Smoke Emission.—Undoubtedly the greatest difficulty in the matter of firing of solid fuel in furnaces heating up from cold is the emission of an undesirable quantity of black smoke, and a continuance and possibly even an extension of the use of this form of heating for the purposes described is bound up with the solution of the problem of the combustion of solid fuel without the emission of black smoke. The subject is a wide one, and it bristles with difficulties in some directions, but the possible low cost of heating practicable for certain classes of heating make it a profitable line of inquiry. At a recent symposium on the subject held by the London Section of the Society of Chemical Industry the author emphasised the importance

of the control of the air for combustion, and the practicability of combining by means of the use of modern heat-resisting steels a measure of preheat to the primary as well as the secondary air. Another important factor is the design and manner of construction of flues and dampers. Such provision assists in reducing the production of smoke.

Finally, in reviewing this question, the aspect should not be overlooked of its effect on the prosperity of the coal industry, and therefore indirectly of the nation as a whole. The fuels alternative to raw coal are derivatives of coal, with the exception of imported oil. The problem of the production of oil from coal is a long way from solution in so far as any extensive effect may be produced, and its major considerations are bound up with the demands of the internal combustion engine. Because of the high adaptability value of oil for this purpose, its price must always be higher for equal heating value than that of coal. The ultimate determinative factor in the selection of any fuel must be the overall cost of the heating operation as distinct from the cost of the potential heat. In the case of coal, the problems of economical handling and combustion constitute the chief criteria of its value for any furnace purpose, and despite the progress of gaseous and electrical heating, it cannot be said that finality has yet been reached in the matter.

There is, accordingly, in this country of good coals, with its wide range of variety, considerable scope for the improvement of solid-fuel firing beyond its present stage of development.

Corrosion of Mild Steel and Alloys *by* Hydrogen Sulphide at 500°C

THE results of an investigation conducted with the object of determining the corrosion resistance of various steels, particularly alloy steels, and aluminium when subjected to the action of moist and dry hydrogen sulphide at 500° C. and atmospheric pressure, are given by A. White and L. F. Marek. The metals used were mild steel, containing 0·23% carbon, cold-rolled aluminium, and a series of alloys, the compositions of which are given in Table I. The conditions employed in the experiments were such as to afford a simple and rapid method of studying the action of hydrogen sulphide on metals. The metal specimens were exposed for different lengths of time, the maximum period being about one month. The loosely adhering scale was removed from the samples with steel wool, and any scale that adhered very closely was removed by pickling in 10% hydrochloric acid, containing about 2% of a pyridine residue inhibitor. The corrosion rates, expressed as penetration in centimetres, or centimetres per year, were calculated from the loss in weight of the samples by use of the appropriate factors.

The experimental data for the metals tested are shown in Table II. Figure 1 represents graphically the corrosion of mild steel and several alloys by moist hydrogen sulphide at 500° C. and atmospheric pressure.

TABLE I. Composition of Alloys.

Alloy.	Carbon.	Manganese.	Phosphorus.	Sulphur.	Silicon.	Chromium.	Nickel.	Vanadium.	Tungsten.	Iron.
A	0·12	0·50	0·03	0·03	0·50	17·0—19·0	8·0—9·0	—	—	Balance
B	0·35	0·24	0·03	0·02	0·22	14·36	0·28	—	—	Balance
C	0·11	0·28	0·02	0·02	0·10	12·75	0·27	—	—	Balance
D	0·40	0·56	0·03	0·03	0·20	0·99	2·20	—	—	Balance
E	0·33	0·61	0·04	0·03	0·25	1·08	—	0·22	—	Balance
F	0·30	1·37	0·03	—	0·07	11·65	63·0	—	2·52	Balance

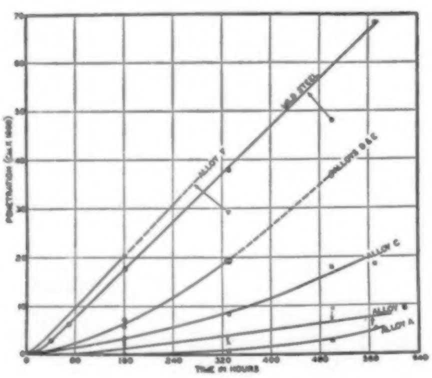


Fig. 1.
Corrosion of Mild Steel and Alloys by Hydrogen Sulphide.

TABLE II.

Corrosion Rate of Steel, Alloys, and Aluminium in Moist Hydrogen Sulphide
(Temperature, 500° C.; Pressure, atmospheric.)

Time, Hours.	Penetration (cm. × 1,000).							
	Mild Steel.	Alloys. A	B	C	D	E	F	Aluminium [1]
20	0·322	—	—	—	—	—	—	—
40	2·75	—	—	—	—	—	—	—
70	6·15	—	—	—	—	—	—	—
160	17·6	0·183	2·55	3·46	7·1	5·64	20·4	—
330	37·8	0·758	2·27	8·30	19·40	19·25	29·0[2]	—
500	47·9	2·75	9·12	17·7	36·5[2]	37·1[2]	—	No evidence of attack
570	68·1	5·35	5·35	18·4	—	—	—	—

[1] Cold-rolled.

[2] Specimen failed by pitting, and the value given is, hence, lower than the true rate.

In general the results indicate that the rate of corrosion for the alloy steels decreases with increasing chromium content, and lead the authors to conclude that high-chromium steels, containing 12 to 20% chromium, have very good resistance to attack by moist hydrogen sulphide at 500° C., and that the presence of high proportions of nickel are detrimental to this protection by chromium. The investigations show that while some protection is apparently afforded by the thin scale present during the early stages of the attack, the thick scale formed by hydrogen-sulphide corrosion is non-protective.

It was shown that the corrosion of aluminium is negligible when exposed to moist hydrogen sulphide at 500° C. for as long as three weeks.

Ind. and Eng. Chemistry, Vol. 24, No. 8, pp. 859-861.

Institutes Hold Joint Autumn Meeting

Metallurgists' Conference in London.

THE first joint meeting of the Iron and Steel Institute and the Institute of Metals was held in London, September 12—15, at which between 300 and 400 members from various parts of the world attended. The opening session was devoted to a lecture by Dr. H. J. Gough, of the National Physical Laboratory, on "Corrosion Fatigue of Metals," at the Institution of Mechanical Engineers. On September 13 a joint technical session of the two Institutes took place, in the morning, at the Institution of Civil Engineers, when five papers were presented. During the afternoon separate sessions were held at the Institution of Civil Engineers and the Institution of Mechanical Engineers, respectively. Separate technical sessions were also held the following morning.

In the evening of September 13 a conversazione was given at the Science Museum, South Kensington, the guests being received by Sir Charles Wright, Bart., K.B.E., C.B., President of the Iron and Steel Institute, and Sir Henry Fowler K.B.E. LL.D. D.Sc., President of the Institute of Metals. A feature of the evening's entertainment was a display of popular and scientific films by the Western Electric Co. These included films showing the Amphibious Tank of Messrs. Vickers Ltd.; the crystallisation of Martensite, prepared by Dr.-Ing. H. J. Wiester; and Welding Construction by the Oxy-acetylene Process, which was lent by the Acetylene and Welding Consulting Bureau.

The comprehensive programme also included visits to the National Physical Laboratory, General Electric Company's research laboratories, the Acton Refinery of The Mond Nickel Co., Ltd., and the Dagenham Works of the Ford Motor Co., Ltd. Arrangements were made for the ladies to join these visits, but an alternative visit to Greenwich Hospital, with its painted hall, Royal Naval museum, and chapel, was also arranged and attracted a large number.

At the technical sessions some thirty-one papers were presented, but in view of the limited time available discussion was somewhat curtailed and some papers were taken as read. It is only possible to summarise them here.

IRON AND STEEL INSTITUTE.

Metallurgical Problems Arising from Internal-combustion Engine Valves.

During a period covering many years' experience makers of internal-combustion engines have tried as valves almost every possible type of material from cast iron to the most complex alloy steels, but so many variables are involved that it is not possible to deduce an ideal valve composition from the metallurgical evidence available. The subject is discussed in a paper by J. R. Handforth, M.Sc., in which the essential properties of valve steels, as stated by previous investigators, are given. The desired properties of these steels are frequently incompatible, and it is necessary in practice to choose materials with properties most suitable to the conditions under which they have to serve.

Users of internal-combustion engines have tested as valves a very great number of steels, both simple and complex, and information has been obtained with regard to the value in valve steels of most of the elements normally used in steel manufacture; but the author points out that comparatively small use has been made of the element manganese, the effect of which is to promote the formation of austenite, and thereby to raise the recrystallisation temperature and increase the hot-tensile strength. Modern valve steels successfully meet the need of great strength and high notched-bar value at working temperatures, and other requirements concerning freedom from forging cracks, heat-treatment without residual strains, and capacity to be hardened at the ends of the stems, now offer little or no difficulty. The hardening and the distortion of valves in service have been eliminated by the use of steels of high thermal change points, such as silchrome, or by the use of austenite steels. The troubles which formerly arose through the scaling of valves have been almost eliminated. But this latter difficulty has been reopened by the increasing use of fuels containing ethyl fluid, of which the products of combustion are more corrosive than those of ordinary fuels. Much research is at present being undertaken to solve this difficulty. The austenitic valves with a high nickel content appear to be most resistant to corrosion of this type, and distinct improvement has been obtained by reducing the working temperatures of the valves.

Efforts have been made to increase the service obtained from valves by welding stellite on to their seats. By this means the seats are rendered exceedingly hard both at normal and at working temperatures. This appears to eliminate entirely the wear and distortion which occur under normal running conditions. This application of stellite by welding gives rise to interesting metallurgical problems. Silchrome valves were successfully treated in this manner, but the stellite applied to cobalt-chromium steel valves invariably cracked. When austenitic valves were so treated, exceedingly coarse structures were sometimes produced owing to the poor heat conductivity of these steels. Such coarse structures cannot be removed by heat-treatment. It has been shown, by a study of these coarse structures, that when austenitic valve steels are heated above 600° C. great changes in microstructure take place. These changes consist essentially in the deposition and rearrangement of carbides, and they appear to be identical with the changes which give rise to "weld decay" in the low-carbon austenitic steels of the 18/8 type.

Nickel-Chromium-Silicon Cast Irons.

A paper by A. L. Norbury, D.Sc., and E. Morgan, M.Sc., deals with an investigation the chief result of which has been the development of an austenitic cast iron by the British Cast Iron Research Association, known as Nicrosilal. This alloy, which contains about 18% of nickel, 6% of silicon, 2% of chromium, 1·8% of carbon, and 1% of manganese is shown to be exceptionally resistant to growth and scaling, and is also remarkably ductile; in consequence, it is not liable to the cracking on sudden heating or cooling, which was the defect—for certain purposes—of the Silal cast irons produced by this Association, from which Nicrosilal has been developed.

This special iron can be melted in the cupola, and there is no difficulty in obtaining total carbon contents as low as 1·8% or less from such melts, since the 4·3% eutectic carbon content of pure iron is reduced by the presence of 6% of silicon and 20% of nickel to about 2% of carbon. The iron solidifies at about the same temperatures as low-phosphorus, high-quality grey iron, but requires somewhat more feeding, since its graphite content is lower. It is easily machinable, gives a fine surface finish, and can be burnished and surface-hardened by cold-work. It is non-magnetic, has an electrical resistivity of about 160 microhms per $cm.^3$, and has good corrosion-resisting qualities, which are improved by the addition of copper.

The composition may be varied over certain ranges, depending on a number of factors; thus, the growth resistance is largely dependent on fine graphite structure, which may be obtained by reducing the total carbon

content, or increasing the chromium content, by superheating, or by additions of steel to the melt. Reducing the total carbon reduces the castability and increases the tendency to solidify white in thin sections, and for most purposes a total carbon content of about 1·8% gives the best compromise. Further, the matrix must be austenitic and not martensitic for good machinability; this necessitates a nickel content of 18% when no chromium is present; this, however, is progressively lowered to 13%, as chromium is increased to about 1·8%, producing an alloy which has the property of being hardened by cold-work, and, in certain cases, it is necessary to increase the nickel content to about 20% and lower the silicon to about 5% to reduce this tendency.

The Equilibrium of Non-metallic Systems.

A complete solution of the problem of slag in iron and steel implies a full knowledge of the equilibrium diagrams of the systems which contain metallic iron and non-metallic compounds of iron and metalloids. These include oxides and sulphides, as well as compounds of iron and other radicals, such as iron silicates. With the object of gaining information of the temperatures of solidification of these objectionable inclusions, the systems FeO — MnO, MnS — MnO, MnS — $MnSiO_3$, and MnS — Fe_2SiO_4 have been investigated, the results of which were presented at the autumn meeting of the Iron and Steel Institute held at Swansea last year, and the present paper by Prof. J. H. Andrew, D.Sc., and W. R. Maddocks, B.Sc., marks the completion of the programme then outlined. It deals with the determination of the equilibrium diagrams of the systems $MnSiO_3$ — Fe_2SiO_4 and FeS — Fe_2SiO_4.

A matter of some importance which may be related to work of this nature is the characteristics of the intentionally added inclusions in free-cutting steels. The form which these inclusions take have, it is known, an important bearing upon the cutting properties of the steel, and it is quite possible that this may depend upon their composition. The authors state that it is proposed to investigate this problem at an early date.

Time-potential Curves on Iron and Steel and Their Significance.

The resistance of iron and steel to corrosion depends largely on the formation of protective skins, and the research described in a paper by Messrs. T. P. Hoar and U. R. Evans is designed to ascertain the factors which promote self-repair or breakdown of these films. Since the factors which depress the potential turn out, on the whole, to be those which are believed to militate against good performance under service conditions, the authors consider that the new method described may have occasional value as an industrial testing method for special purposes. The method, however, must be applied with due regard to the complexity of the position, and is not suitable for routine testing.

The new method refers to the potential of a single point of a surface freely exposed to air or oxygen, by which time-potential curves have been worked out, depending on the use of a frayed filter-paper strip soaked in electrolyte and touching the metal at the point requiring examination; this gives information on the behaviour of the oxide film, a rising curve showing repair and a falling curve breakdown. Curves for iron and steel show at first rapidly falling potentials in chloride and sulphate solutions; the tendency to breakdown is greater at rough places than at smooth. In a phosphate solution there is a rise from the first, indicating self-repair of the film. Liquids containing chromate also show a tendency to repair if sufficient be present: repair is, in general, more easily effected in the sulphate solution than in chloride, it is easier with pure iron than with steel, and easier with smooth surfaces than with rough. Specimens of pure iron pretreated in chromate and placed in sulphate solution show an elevated potential at first, and then quite suddenly breakdown occurs; in chloride solution, and also with steel similarly pretreated in chromate, the breakdown occurs much more quickly. Alloys containing chromium tested in plain chloride solutions, give rising, level, or falling curves according to the conditions.

Effect of Hydrogen Sulphide on the Corrosion of Iron by Salt Solutions.

The stimulation of attack on iron by small quantities of sulphur compounds possesses considerable theoretical interest, and, since hydrogen sulphide occurs in polluted waters, it has also a practical importance. In order to ascertain the true causes of acceleration an investigation has been made on a number of steels by S. C. Britton, T. P. Hoar, and U. R. Evans, which is described in this paper. The authors did not seek to estimate the effect on service life under any particular conditions, but merely to locate the cause underlying the surprising effect of solutions with small sulphur additions on steel immersed in them. The investigation indicates that small additions of sodium sulphide (less than five parts per million) to potassium chloride solution accelerate the total attack on vertical half-immersed steel, mainly by eliminating the anodic reaction. Nevertheless, under the particular conditions of the experiment the intensity of attack is diminished, because the area attacked is extended owing to the precipitation of iron salts as non-protective iron sulphide, and consequent interference with the usual protection mechanism.

Scale Removal by Acid Pickling.

A record of both laboratory and works investigations on the physical chemistry of scale removal from mild steel has been made by A. R. Winterbottom, M.Sc., F.I.C., and J. P. Reed, members of the Research Department of Tube Investments, Ltd., under the direction of Dr. J. W. Jenkin. Descaling is almost invariably accomplished by pickling, so that pickling is an essential stage in the production of cold-finished steel products, which influences the economics of the whole production process. The general scheme of the work included examination of the condition of the material to be pickled; investigation of the physical chemistry of the pickling process; discussion of the applications of the results of the foregoing with a view to obtaining the best commercial efficiency; and notes on simple control methods.

The results of the etching experiments and also the quantitative investigations seem to establish the fact that the mechanism of scale removal is the same in the case of dilute sulphuric and hydrochloric acids, and by inference in the case of any acid forming soluble ferrous salts. When there is a ferrous-oxide phase layer adjacent to the steel base, as is normally the case, detachment of the outer layers follows solution of the ferrous-oxide phase by acid which has gained access to it via pores and cracks in the outer layers.

The authors consider that the time necessary for removal of scale is dependent on: (*a*) The temperature and time of formation of the scale, that is, the amount of ferrous-oxide phase and its accessibility as determined by the condition of the outer layers; (*b*) the hydrogen ion activity of the acid solution; (*c*) the viscosity of the solution; (*d*) the temperature; (*e*) the iron salts; (*f*) agitation. Of these, the temperature, both directly and also by its influence on (*b*) and (*c*), has by far the most important effect on the time of pickling a given material. The relations between the pickling time, temperature, and acid concentration in the case of a standard material are in accord with the kinetics of a heterogeneous reaction, as is to be expected.

The acid consumption, apart from mechanical losses, is generally determined by the amount of scale and the proportion that is soluble (that is, the ferrous-oxide phase). Wherever it is possible to arrange for heating, sulphuric acid should normally be preferred on grounds of much lower cost, even allowing for heating charges.

The variations in thickness of the scales examined indicate that economy in the pickling department is dependent on the annealing conditions, as well as on the organisation of the pickling practice in such a way as to obtain the maximum utilisation of the acid.

The Generation of Steam from Blast-furnace Gas.

The work of the Iron and Steel Industrial Research Council during recent years has included a number of investigations into problems of heat and power production and utilisation in British iron and steel works. In the course of this work it has become apparent that the question of boiler efficiency is of the first importance, owing to the heavy demands made by the steam-raising plant upon the sources of fuel available, and, in consequence, a study has been made of boiler practice in the iron and steel and other industries, especially that of electric-power generation. One aspect of the main question, that of generation of steam from blast-furnace gas, is considered in a paper by A. F. Webber, B.Sc., in which he stresses the importance of boiler efficiency as a factor affecting the works heat balance by various examples from practice. He compares the boiler efficiencies usually attained by industrial plants with standards maintained in power-station boiler-houses.

It is shown that high thermal efficiency is possible despite the fluctuating nature of a steelworks steam load, and the disadvantages attached to the use of blast-furnace gas as a boiler fuel. The latter are partly compensated by certain advantages as compared with coal-firing. The disadvantages of blast-furnace gas, it is stated, can be overcome by the use of preheated air, properly controlled, for combustion. This will result in high combustion temperatures, with increased output from the boiler, while the maximum amount of heat can be abstracted economically from the flue gases. It is suggested that where the blast-furnace gas has been cooled by cleaning, both air and gas should be preheated, the feed-water being heated to the maximum practicable temperature by exhaust steam.

The economic results of efficient steam-raising plant are illustrated by calculations, which, based on general experience, will serve as examples, although the decision at any individual works will naturally depend on the combination of many factors local to the installation.

Light-weight High-pressure Gas Cylinders.

Recent developments in the use of high pressures, particularly in the case of permanent gases, have led to experimental work being undertaken to produce lighter cylinders. Improved manufacture of alloy steels has resulted in the production of alloy-steel cylinders, an investigation on which forms the basis of a paper by Frank S. Marsh, M.Sc. No attempt is made to discuss all the uses of the cylinders, but a record is given of the results of various tests. The use of coal gas for commercial vehicles driven by internal-combustion engines has been receiving much attention, and alloy-steel cylinders appear to be satisfactory, but it will be realised that all fear of bursting or fragmentation must be eliminated.

The author describes a number of tests undertaken with containers made from two typical steels of the following analysis :—

	C.	Si.	Mn.	S.	P.	Ni.	Cr.	Mb.
A ..	0·310	0·160	0·490	0·050	0·038	2·620	0·710	0·380
B ..	0·280	0·190	0·490	0·032	0·030	3·320	1·120	0·470

Steel A was air-hardened from 850° C. after being heated for 80 mins. and tempered at 600° C. for 90 mins. Steel B was air-hardened from 820° C. after being heated for 90 mins. and tempered at 650° C. for 90 mins.

The tests included hydraulic-pressure tests and bursting tests, physical tests, and chemical analysis, rough-handling, crushing and bullet tests. The results appear to be satisfactory, and indicate that light-weight high-pressure containers can be relied upon.

Fatigue Resistance of Unmachined Forged Steels.

Previous investigations have shown that the fatigue resistance of spring steels is influenced to a considerable extent by the condition of the surface of the material. In unmachined heat-treated rolled plates, for instance, used for ordinary laminated springs, it has been found that the endurance fatigue limit may be appreciably less than one-half of that of the same material when machined and polished. This, of course, applies also to other steel components which are subjected in service to alternating or repeated stresses without the material being machined and polished subsequent to manufacture and heat-treatment. Little is known of the resistance to fatigue of material in this condition, and this investigation has been carried out at the National Physical Laboratory as part of the work on the effect of surface conditions on the fatigue resistance of steels. In this investigation, which is described in a paper by G. A. Hankins, D.Sc., and M. L. Becker, Ph.D., the main object has been to determine the fatigue resistance of certain representative steels when tested in the condition in which they are often used in service, namely, as unmachined heat-treated forgings.

The work was carried out by means of rotating bending fatigue tests on unmachined forged test-pieces, and on normal machined and polished test-pieces. The steels used were a 0·2% carbon steel, a 0·4% carbon steel, a 3% nickel steel, and a nickel-chromium steel, obtained from two representative British manufacturers. Microscopic examinations for the detection of surface decarburisation were also made, in addition to tensile tests, hardness tests, and Izod tests. Somewhat similar fatigue tests were also made on rolled mild-steel bar.

The results are summarised in the accompanying table. It is concluded that the effect of the unmachined surface

SUMMARY OF RESULTS OF FATIGUE TESTS ON FORGINGS.

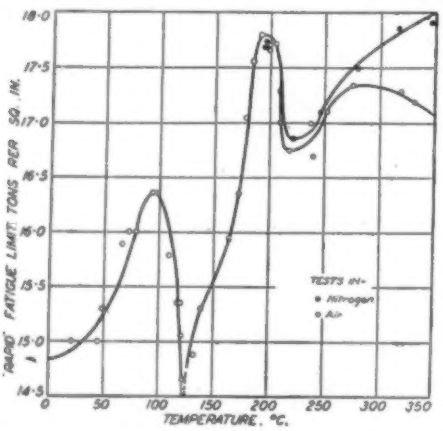
Description of Material.	Manufacturer.	Average Brinell Hardness Number. 1.	Average Tensile Strength, Tons per Sq. In. (Estimated from Col. 1.) 2.	Endurance Fatigue Limit, Tons per Sq. In. As Forged. Type (*a*) Specimens. 3.	Endurance Fatigue Limit, Tons per Sq. In. Machined and Polished. Type (*b*) Specimens. 4.	Ratio. Col. 3. / Col. 4 5.	Ratio. Col. 3. / Col. 2 6.	Ratio. Col. 4. / Col. 2 7.
0·20% carbon steel	*A*	135	30	±12·1	±14·2	0·85	0·40	0·47
	B	149	33	±11·7	±14·7	0·80	0·35	0·45
0·40% carbon steel	*A*	205	45	±16·5	±21·0	0·78	0·37	0·47
	B	185	41	±12·7	±21·6	0·59	0·31	0·53
3% nickel steel	*A*	274	59	±15·0	±32·5	0·46	0·25	0·55
	B	240	52	±15·8	±27·9	0·57	0·31	0·54
Nickel-chromium steel	*A*	308	66	±18·0	±31·5	0·57	0·27	0·48
	B	278	60	±14·4	±31·0	0·46	0·24	0·52

on the fatigue strength of forgings is not very marked for mild steel, but is of very definite importance in the case of steels which are heat-treated to give high tensile strength. For the 3% nickel and nickel-chromium steels the endurance fatigue limits were ± 14 to ± 18 tons per sq. in. when unmachined, and ± 28 to ± 31 tons per sq. in. when machined and polished. For the one material investigated, the effect of the "as-rolled" surface on the fatigue strength of rolled mild steel was small.

The Endurance Limit of a 0.33% Carbon Steel at Elevated Temperatures.

Investigations have shown that certain of the physical properties of iron and steel exhibit points of inflexion as the temperature is raised. No attempt, however, has apparently been made to detect these change points in the fatigue-resisting properties of metals. Previous work relating to low-temperature change points of iron and steel prompted an investigation into the fatigue properties of a 0·33% carbon steel, the method and results of which are given in a paper by J. W. Cuthbertson, M.Sc.

The results of a series of tests are plotted in the accompanying graph. The most interesting points on the curve are the minimum at 123° C. and the maximum around 195° C. At high temperatures the curve of the tests made in air falls owing to surface oxidation of the specimen. The tests conducted in nitrogen show little difference up



Results of tests on fatigue properties of a 0.33% carbon steel.

to 220° C., but above this the fatigue limit increases slowly, the curve departing more and more from that for tests in air.

The practical significance of this work is the minimum value recorded at 123° C., which may have an important bearing on the design of machines normally operating at about this temperature. A dangerous zone appears to exist between 120° C. and 125° C., and should be avoided or taken into consideration in design. The maximum at 195° is less important. The increase in fatigue strength here is not sufficiently great to warrant putting it to any practical application. It is wiser merely to regard this increase in strength as a fortunate outcome of the effect of heating.

Spectroscopic Estimation of Nickel Manganese and Chromium in Steels.

In a previous paper Twyman and Fitch[2] described the spectroscopic estimation of various constituents of steels. Graphs were shown connecting the length of a spectrum line with the percentage of the element present. The marked curvature of the graphs, however, presented difficulties in obtaining an accurate interpretation of the results, while the curves showed no obvious relationship between line-intensity and percentage. It has been found that the spectrographic estimation of various constituents of steel is simplified by plotting the logarithm of the percentage of the constituent present against the logarithm of the intensity of a spectrum line of that constituent. Over considerable percentage ranges the graph connecting these two quantities is linear, hence, once two points on the graph have been determined, the estimation can proceed immediately.

A method is given in a paper by F. Twyman, F.Inst.P., F.R.S., and A. Harvey, Ph.D., B.Sc., whereby, instead of actually evaluating intensities, the lengths of the lines as given by the logarithmic sector are employed, and an accuracy of the order of 10% of the content is obtainable in the estimation of nickel, manganese, and chromium. The authors point out that in further researches of this kind it is evident that the chemical analyses should be checked spectrographically (especially where small percentages are being estimated), particularly by the spectrographic examination of the precipitate after weighing, and also, perhaps, of certain of the liquids, to ascertain that the precipitation has been complete.

[2]Journal of Iron and Steel Institute, 1930. No. 2, p. 289.

Veining of Sub-boundary Structures.

Ferrite, which has been deeply etched alternately with a cupric reagent and picric or nitric acid, sometimes reveals within the α grains a network, variously termed veining or sub-boundaries. As a result of the examination of a number of alloys it has been found that the structures are not limited to ferrite, but may extend to alloys containing either a single metal or a solid solution as a separate constituent. The occurrence of veining in metals and alloys has been discussed by many workers, and in view of contradictory evidence, and conclusions adduced by these workers, an attempt has been made to elucidate the mechanism of the formation of veining as it occurs in non-ferrous as well as ferrous alloys, although the experimental work described in this paper by L. Northcott, Ph.D., M.Sc., A.I.C., deals primarily with steels.

It is possible to have four different networks of some iron-carbon alloys, but the author confined his discussion to the α-veining structures occurring within individual α-iron grains. The material forming the basis of the following experiments was an open-hearth steel of the following composition: Carbon, 0·30; silicon, 0·23; manganese, 0·63; sulphur, 0·03; and phosphorus, 0·05%. Two samples of wrought iron, one electrolytic iron and an Armco iron were examined. Electrolytic nickel, B.E.R.-quality copper, and a sample of electrolytic copper were also examined.

The result of the experiments indicate that (1) veining may be induced in iron, nickel, and copper by annealing at a high temperature (1,000° C.) in an oxidising atmosphere; (2) veining may be induced in iron by annealing in contact with pure iron-oxide; (3) veining may be removed from the same metals by annealing in hydrogen; (4) veining was found in mild steel, iron, and copper which had been cast, but not in iron, nickel, or copper as deposited electrolytically; (5) veining could be obliterated in iron by quenching from above the A_3 point, and in copper by quenching from 1,000° C.; (6) on slow cooling, the veining started to appear in iron below the A_3 point, but was not complete until atmospheric temperature was reached; (7) on heating an iron in which the formation of veining had been prevented by quenching from above the A_3 point, veining was observed on annealing at 300° C. for 20 hours, but was not appreciable until 600° C. was reached; (8) veining could be re-formed in quenched copper by slow cooling; (9) slight veining was induced in electrolytic iron by annealing in contact with iron oxide at a temperature *below* the A_3 point.

The Constitution of the Fe-C-Si System.

The results of a study on the constitution of alloys which contained up to 6% of silicon and up to 4% of carbon were communicated in a paper by A. Kriz, Ing.Dr., and F. Poboril, Ing.Dr., and published in the *Journal of*

the Iron and Steel Institute, 1930. In the present paper the data on alloys with 4 and 6% of silicon are supplemented with the results of thermal analysis during solidification, and the authors present the results of a further investigation on the constitution of alloys in the range between 8 and 16% silicon.

Altogether, 50 alloys have been investigated, and the results of metallographic, thermal, and dilatometric analyses permit the authors to establish the three-dimensional constitutional diagram of the stable and metastable phase equilibria. These were plotted at 4, 6, 8, 10, and 16% of silicon (parallel with the plane of the binary system Fe - C), and at 0·10, 0·22, 0·52, and 2·54% of carbon (parallel with the plane of the binary system Fe - Si). Based on these pseudo-binary sections isothermal sections through the space diagram were constructed at 1,000°, 1,160°, 1,170°, and 1,300° C. The space model is illustrated by the projections of the equilibrium lines upon the planes of the binary diagrams Fe - C and Fe - Si, and upon the concentration plane.

The Growth of Austenite Above Ac_1 in Plain Carbon Steels.

A number of observations on the tendency of pearlite to form a network in mild steels which have been normalised at some temperature within the critical range indicated that at the Ac_1 point the carbide begins to pass into solid solution, and in hypo-eutectoid steels the austenitic areas thus formed gradually increase in size, as the temperature is raised, by absorption of the surrounding ferrite, and this paper by J. H. Whiteley, F.I.C., deals chiefly with the manner in which this austenitic growth occurs.

The evidence advanced shows that the austenite areas do not expand equally in all directions, but prefer to move along the boundaries of the ferrite grains, this movement becoming increasingly pronounced as the rate of heating is retarded. As a consequence, a broken network of pearlite and cementite films may be formed in the steel when it is cooled.

A variety of samples were used for the experimental work, but since the growth of the austenite was found to be of similar character in each with modifications according to composition, only three are described.

An explanation of this effect, which can be produced to a very marked degree in some steels, has not been found. It may be that several factors are involved, three of which are by the author, namely, (1) differences between the thermal expansions of the ferrite and the austenite, (2) surface energy adjustments at the ferrite-austenite interfaces, and (3) differences in the rate of solution of ferrite in austenite such that the ferrite at the boundaries is more readily soluble than that within the grains. During the course of the investigation no observation has been made from which any definite elucidation of the problem could be reached, yet, notwithstanding, the results obtained will be of interest.

In addition to the influence of a slow rate of heating in facilitating the movement of austenite when formed as isolated areas at Ac_1, the manganese content of the steel also has a strong influence. When present only in minute quantity the boundary movement did not occur below 780° C. with the slowest rate of heating used in the investigations, but it appeared at higher temperatures. The movement is modified, and may be almost completely suppressed by ferrite heterogeneity such as that which produces the banded structure in rolled steels.

The extent of the movement is increased by repeated heatings, provided that the intermediate coolings are not too slow. An almost complete network of austenite may thus be obtained. The structure formed from an austenite network at Ar_1 under normal cooling rates consists of broken films of cementite and pearlite at the grain boundaries. It causes a definite lowering of the Izod impact value.

INSTITUTE OF METALS.

Modern Works Plant and Equipment for the Hot-rolling of Nickel and Nickel Alloys.

Close interdependence of the metallurgical, engineering, and operating factors are necessary in the production of metals and alloys involving high-temperature work, and W. R. Barclay, O.B.E., G. A. V. Russell, Wh.Ex., and H. Williamson discuss the factors governing the design of lay-out and plant at the works of Henry Wiggin and Co., Ltd. The paper gives the result of experience in the hot-working of nickel and its alloys, and a close study of the conditions under which similar work is carried out in Europe and America. The main features of the plant are a 750-ton hydraulic forging press and a hot-rolling mill. The latter consists of an 18-in. three-high universal type mill with horizontal and vertical rolls for the production of sheet, bar, and strip ; and a 52-in. three-high Lauth type sheet mill for the rolling of sheet-bar and small rectangular ingots into sheets, together with the auxiliary equipment necessary for heating and for handling and disposing of the rolled product.

The plant is described in detail and diagram and illustration are given, while various methods of practice in other countries are compared and underlying principles discussed. The methods of production adopted in working the plant are also described. Attention is directed to a special semi-continuous electric furnace for heating sheet-bar for the Lauth mill. This furnace is double-ended, the material is carried through by a walking beam, and metal rods are used to support the charge. The furnace is heated by means of silicon carbide (" Globar ") elements arranged vertically in each side of the chamber.

A concluding part of the paper deals briefly with the hot-working of nickel and such alloys as are intended for use at high temperatures, particularly to problems which arise from the necessity for obtaining and maintaining temperatures of the order of from 1,000° C. to 1,300° C. during working ; and the heating of ingots, billets, etc., in an atmosphere as free as possible from deleterious gases, with the avoidance of excessive oxidation.

Mould Materials for Non-ferrous Strip Ingot Casting.

Grey cast iron has long been regarded as the most suitable available material for moulds for non-ferrous strip ingot casting, and it has not been generally realised that while cast iron possesses many advantages, it is capable of introducing ingot defects, the source of which has frequently remained unexplained or has been attributed to other causes. The subject has been studied as part of a comprehensive research on the casting of 70-30 brass strip ingots carried out in the Research Department, Woolwich, for the British Non-Ferrous Research Association. The results of the experimental work in this section are given in a paper by G. L. Bailey, M.Sc.

Apparently cast-iron moulds are subject to two particular defects : Gas evolution from the face of the mould when this is overheated during pouring (" blowing "), and transverse cracking of the working faces. The conditions producing blowing have been studied and the gas has been found to originate in a reaction between the carbon of the iron and a superficial oxide film. Transverse cracking of the cast-iron mould surface is due to stresses resulting from a high-temperature gradient in the mould wall immediately after casting.

A number of materials have been examined and it has been found that mild steel moulds, which are free from " blowing " and cracking, are liable to serious distortion resulting from stresses set up immediately after casting. Ingot moulds free from warping can be made from a material having a sufficiently high elastic limit (at both low and raised temperatures) to avoid plastic deformation under the thermal stresses induced during casting. Experimental trials have shown that a mould of nickel-chromium-molybdenum steel, suitably heat-treated, is satisfactory in

this respect, but is subject to other disadvantages and is somewhat costly. From all points of view it is considered that copper is the most suitable material for brass strip ingot moulds, either as a solid mould of slightly greater thickness than the cast-iron moulds at present in use, or as a thinner water-cooled mould. The high thermal conductivity of copper prevents serious temperature gradients and obviates the surface difficulties associated with cast iron, while affecting the structure and soundness of the ingots but little.

Some Reactions Occurring in "Hot-dipping" Processes.

Evidence was adduced from an investigation by Daniels to show that at normal galvanising temperatures—*i.e.*, below 480° C.—the zinc-iron alloy, approximately $FeZn$[1], which forms on the surface of articles being galvanised, is stable with respect to molten zinc, and remains firmly attached to the steel surface. It is highly improbable, therefore, that the reaction between molten zinc and iron is the source of the dross or hard zinc which accumulates at the bottom of the galvanising kettle.

It has been noted by several observers that molten zinc will decompose iron chloride with the formation of iron, and it is shown that, when mild steel articles are galvanised contamination of the zinc will occur as a result of reduction of iron salts from the flux. The factors affecting the entry of iron salts into the flux have been studied and form the basis of a further paper by Edward J. Daniels, M.Sc. The paper gives quantitative data on the sources of iron salts in galvanising flux, and shows how these lead to the formation of "dross."

A theory of the action of fluxes in hot-dipping processes is advanced and evidence given in support. The author concludes that contamination of the liquid metal ("drossing") is a normal accompaniment of hot-dipping processes, and methods for controlling it are indicated.

Coating steel with cadmium and lead by hot-dipping has been brought in line with tinning and galvanising by the discovery that these metals can form compounds, $FeCd_2$ and $FePb_2$, with iron. These compounds are both magnetic, have high melting points, and are lighter than cadmium and lead respectively, so that the drosses rise to the surface of the liquid baths. In both cases the molten metal is insoluble in the compound, so that its formation on the surface of the steel being dipped effectively shields it from further attack.

The action of molten tin on an 8% "aluminium-bronze" is shown to result in the formation, on the bronze surface, of a solid solution of tin and aluminium in Cu_3Sn, which is only partially wetted by molten tin, making it impossible to solder the "bronze" successfully.

The Effect of Pressure on the Liberation of Gases from Metals.

The study of gas porosity in metals is much hampered by the lack of precise knowledge as to the conditions necessary for the appearance of gas bubbles in a solidifying metal. The assumption that bubbles are formed as soon as the amount of gas dissolved in the metal exceeds the solubility of the gas in the metal breaks down when it is considered that the solubility of a gas in a metal depends on the partial pressure of that gas in the vapours surrounding the metal, and it is not known what partial pressure of the gas in question in the neighbourhood of a solidifying ingot is to be assumed. A method of approaching the problem is presented in a paper by N. P. Allen, M.Met., which refers more particularly to silver and oxygen.

In an investigation the author studied the liberation of oxygen from silver during solidification by means of cooling curves. It was found that the gas is evolved when the "internal pressure" of the dissolved gas becomes greater than the hydrostatic pressure of the liquid metal, and that by applying a sufficiently large pressure to the liquid metal, the formation of blowholes can be prevented. The equilibrium of the silver-oxygen system is discussed, and the existence of a eutectic shown. A method of eliminating blowholes in cast metals is recommended. The "internal gas pressures" developed in metals when gaseous constituents capable of interaction are present, are discussed.

The Removal of Gases from Aluminium.

This paper, by J. D. Grogan, B.A., and T. H. Schofield, M.Sc., describes some experimental work, in which mixtures of nitrogen with chlorides were found to be effective in the removal of dissolved gases from certain aluminium alloys. The work was carried out under the direction of the Alloys Sub-Committee of the Aeronautical Research Committee of the Department of Scientific and Industrial Research and constitutes a continuation of the systematic study of aluminium and its alloys which has been carried on at the National Physical Laboratory.

Three treatments were employed in the experiments :—Purified nitrogen with titanium tetrachloride ; raw nitrogen with titanium tetrachloride ; and raw nitrogen with carbon tetrachloride. The results indicate that each of these treatments for the removal of gas yields metal of high density and good mechanical properties. Of the three, that which employs raw nitrogen and carbon tetrachloride is definitely the cheapest and easiest to handle, and is stated to cause far less fumes than the simple chloride process. The quantity of chloride required is quite small : 0·25 c.c. per pound of metal has proved satisfactory even for small melts.

Research on Beryllium.

Details of a research on the preparation of pure beryllium, at the National Physical Laboratory, are described by H. A. Sloman, M.A. In 1926 Dr. Vivian[1] had succeeded in producing solid electro-deposits by the fusion electrolysis of an electrolyte consisting mainly of beryllium and sodium fluorides. The degree of purity achieved was approximately 99·5%. The metal of this degree of purity was entirely non-ductile, and it was thought that if the metal could be prepared in a sufficiently high state of purity it should possess valuable properties differing materially from those of the impure substance. It is shown in this paper, however, that with the progressive elimination of metallic impurities the brittle nature of the early metal was not greatly altered. This brittleness has been found to be due to a beryllium/beryllium oxide eutectic surrounding the metal grains.

Most of the work in this investigation has been directed towards the elimination of this oxide. Of all the methods attempted and described by the author, sublimation *in vacuo* has been the most effective. Even by this method it has not been possible to obtain sufficient metal for determination of its mechanical properties in the pure form. Comparatively thin films of the metal of more than 99·9% purity have, however, been produced. From their properties it is suggested that pure beryllium is likely to be similar in mechanical properties to, for instance, iron —ductile, strong, and of medium hardness (Brinell hardness about 55–60).

During the course of the work a successful method of plating beryllium on other metals from fused electrolytes at temperatures of 600° C. and upwards was found. Certain evidence that beryllium undergoes a transformation at room temperatures has been obtained. Whether this change is associated with the residual impurities or with an allotropic transformation is not yet determined.

Some Attempts at Making Beryllium-Magnesium Alloys.

Various workers have tried to produce alloys of beryllium and magnesium, but so far as R. J. M. Payne, B.Sc., and J. L. Houghton, D.Sc., have been able to find out, without

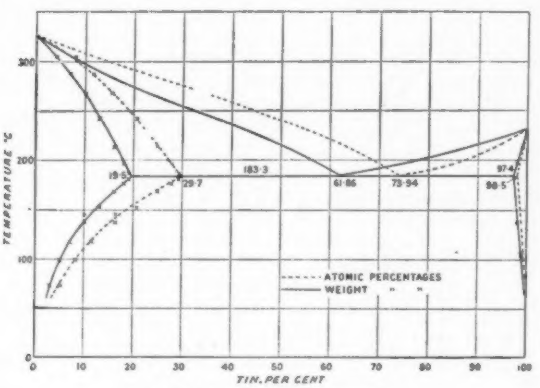
[1] E. J. Daniels, *J. Inst. Metals*, 1931, 46, 81-96.

[1] *Trans. Faraday Soc.*, 1926, 12, 211.

success. Apparently the high melting point of beryllium and the low boiling point of magnesium preclude the melting together of the metals, at any rate under normal pressures, and no action seems to take place between solid beryllium and molten magnesium. The authors give a description of various methods they have tried for the production of beryllium-magnesium alloys, but all have proved abortive. It is suggested that the problem might be solved by the simultaneous electro-deposition of magnesium and beryllium on to the same cathode.

The Constitution of the Lead-tin Alloys.

An investigation of the constitution of the lead-tin alloys is described by D. Stockdale, M.A., Ph.D. Various methods have been used in an examination of the alloys and an equilibrium diagram, which is repreduced here, is given. Compositions are expressed in percentages by weight and also in atomic percentages (broken line). The micrographic method, two thermal methods, and a modified



Lead-tin equilibrium diagram.

electrical conductivity method have been used in the determination of the solubility of tin in lead, which is shown to be 19·5% by weight, at the temperature of the eutectic. This value is considerably higher than any previously obtained. It is also shown that at ordinary temperatures lead probably cannot hold more than 2% of tin in solid solution.

The cause of the evolution of heat in certain of the alloys at a temperature just below that of the eutectic is discussed. No definite conclusion has been reached, but two explanations are put forward, and it is also shown that the allotropic theory is probably untenable.

The data used for the construction of the equilibrium diagram is given in this paper, except that the tin-rich phase boundary is after Jeffrey,[2] the eutectic is placed at 61·86% by weight of tin,[3] and the liquidus is taken from some of the authors' unpublished work. This new diagram differs considerably from previous diagrams.

The Annealing and Grain-growth Characteristics of Alpha Brass.

In investigations involving a study of the effect of additions of different alloying elements in brasses of various types, but more especially α-brasses, it has been observed that the simple form of softening curve of the straight brasses was appreciably modified by many of these additions. Different properties and various characteristics of a wide range of alloys were studied during the course of these investigations, but a paper by Maurice Cook, M.Sc., Ph.D., and Herbert J. Miller, M.Sc., deals exclusively with the annealing characteristics of a few alloys containing additions of iron, phosphorus, manganese, aluminium, aluminium and nickel, and aluminium and silicon. These have been studied with special reference to an abnormality which alloying elements produce on the softening curves. The experimental procedure adopted consisted in determining diamond pyramid hardness values and making grain size measurements on cold-rolled alloys annealed at various temperatures. Tensile properties on a number of alloys representative of the series investigated were also studied.

These elements have been found to exert a retarding influence on the annealing process subsequent to the initial softening, the extent of which varies with the amount and nature of the addition. The effect is shown as a deflection in the smooth hardness-annealing temperature curve which is characteristic for a "straight" brass after the commencement of recrystallisation. Subsequent to the deflection, the annealing curves of brasses containing the specially added elements tend to resume the normal form. The retardation of softening is also accompanied by a retardation in grain growth.

The different elements which have been considered also raise the intrinsic hardness of brass, and in most cases increase the temperature of initial softening on annealing.

The deflections in the softening curves corresponding with delayed or retarded softening subsequent to the commencement of recrystallisation, which have been found to characterise the brasses containing the various additions considered, have also been observed in curves connecting tensile strength and elongation values with annealing temperatures. It is possible that the delayed softening, the extent of which depends on the quantity and nature of the addition made to the brass, may, in the case of some of the alloys at least, be a manifestation of age-hardening properties, but it cannot be assumed that the effect in all the alloys examined is necessarily due to the same cause.

Liquation or "Inverse Segregation" in the Silver-copper Alloys.

The behaviour of certain alloys in regard to the segregation of their constituents during solidification has long been recognised, and many efforts have been made to explain the mechanism and the cause of the phenomenon. The problem has been further investigated, particularly of the behaviour of silver-copper alloys, and a paper by J. H. Watson, M.C., B.Sc., A.R.S.M., describes the experimental work, which appears to show quite conclusively that the phenomenon which was originally referred to as "liquation," and is now perhaps more commonly spoken of as "inverse segregation," is, in fact, correctly described as liquation in the original and true sense of that term. The procedure adopted has had the effect of accentuating the influence of this gravity separation to an extent far beyond that which could be observed in ordinary practice, and has consequently enabled the movement of the primaries to be confirmed by microscopic examination. It has also enabled it to be shown that for all the alloys of the silver-copper series, under the influence of a chilling surface, the first formed primaries, whether of silver or copper, move away from the chilling surface, even against the influence of gravity. Thus, in silver-copper alloys having a solidification interval, primaries are capable of migrating upwards or downwards under the influence of gravity, and of being scattered by the influence of a chilling surface, and of undergoing an alteration in shape and size from the same cause.

The failure of the application of the Ludwig-Soret effect to account for segregation in alloys is seen to be due to the very different nature of the phenomenon in which this effect was originally established. In that case, very dilute salt solutions were considered, and the differentiation observed was concerned with the movement of ions. In the case of the segregation in alloys, however, the movements are those of discrete and relatively large particles, to account for which a physicochemical mechanism, such as is involved in the Ludwig-Soret effect, is necessarily inadequate.

[2] Jeffrey, *Trans. Faraday Soc.*, 1928, 24, 209.
[3] Stockdale, *J. Inst. Metals*, 1930, 43, 193.

Mechanical Properties of Nickel Wires.

Data on certain mechanical properties of fine nickel wires are given in a paper by C. E. Ransley and C. J. Smithells, D.Sc. They have been obtained as a result of tests on fine wires made from commercial nickel, and from laboratory melts containing small percentages of other elements. They include mechanical properties at various temperatures up to 1,000° C. for wires of different diameters, and after annealing at various temperatures. Although it is known that different consignments of commercial nickel wire vary considerably in both strength and ductility, even when the material contains more than 99·5% nickel, no data was available regarding the mechanical properties of nickel wires as fine as 0·04 mm. diameter at normal and elevated temperatures. This investigation was carried out primarily to supply this need.

The results indicate that the annealing temperature of commercial nickel wire which has been reduced 75% by cold-drawing is independent of wire diameter. For the material used this temperature is 640° C. as judged by changes in tensile strength and elongation. For wires annealed below 600° C. the tensile strength is higher the finer the wire, but this is reversed when the wires are annealed above 640° C. This, and similar effects, are attributed to the relative dimensions of the wire and the crystals, which latter may occupy the full cross-section of the wire.

Additions of iron, manganese, or magnesium increase the tensile strength of cold-drawn wire. Whilst fine nickel softens with low-temperature annealing, these wires show a slight increase in tensile strength after annealing below 400° C. The annealing temperature of pure nickel is about 480° C., but this is raised 100° C. by the addition of 2·33% iron, 140° C. by 0·34% manganese, and 160° C. by 0·07% magnesium. Additions of these elements lead to the development of large crystals on annealing above 800° C. with consequent fall in tensile strength and elongation.

Curves representing the tensile strength of wires at temperatures up to 1,000° C. all show an inflection at 300°–450° C. This is practically absent in pure nickel.

The authors developed a simple form of long-period tensile test, or creep test, by means of which the time to fracture under various loads at temperatures ranging from 600° to 1,000° C. was determined for commercial nickel. The curves obtained for periods from 30 secs. to 1,000 hrs. were of the type usually obtained by more elaborate methods, and indicate that the method might be applied to give data on creep over much longer periods.

Atmospheric Action as a Factor in Fatigue of Metals.

This paper, by H. J. Gough, M.B.E., D.Sc., and D. G. Sopwith, B.Sc., deals with the results of tests made, using direct and flexural stresses, on a range of materials tested in air, *in vacuo*, and in air when coated with lanoline grease. The work forms part of a programme of research on corrosion fatigue carried out as a joint investigation at the National Physical Laboratory and the Royal Aircraft Establishment under the general supervision of the Aeronautical Research Committee.

The results indicated that the atmosphere did exert some influence on the fatigue strength, but the quantitative effect was rather obscured by the lack of uniformity of the materials. Further comparative tests were, therefore, made on four materials—mild steel, annealed copper, annealed brass, and cupro-nickel—which previous experience had shown to be very uniform in mechanical properties. In each case, the effect of the grease coating is negligible, but substitution of a vacuum for atmospheric conditions produced the following definitely established improvements in fatigue limits: 5%, 13%, and 26% for mild steel, annealed copper, and annealed brass, respectively. The influence of the atmosphere in ordinary fatigue tests has thus, for the first time, been definitely established, and this is of considerable importance in widening our understanding of corrosion - fatigue phenomena; it also opens up various fields of possible future inquiry. The fatigue limit in air can no longer be taken as a standard, and it appears desirable to investigate the comparative fatigue strength in air and *in vacuo*, of a representative range of sound metals and alloys. The substitution of other contact substances for air has sometimes been found to improve the fatigue resistance: experiments made with a range of such contact substances to determine if the fatigue strength *in vacuo* represents the maximum value would be very informative. A further aspect worthy of consideration is the possible effect of a still higher vacuum than that employed in the present tests; a series of comparative tests should be made in order to investigate this interesting point.

The Distortion of Wires on Passing Through a Draw Plate.

Experiments made with composite copper wires, $\frac{1}{8}$ in. in diameter, have been made by Prof. G. I. Taylor, F.R.S., and H. Quinney, M.A., with the object of studying distortion produced at right angles to the axis of a wire in passing through the die. Each composite wire consisted of two wires of semi-circular section, the flat faces of which were polished and engraved with fine scratches, and subsequently pulled through various draw-plates.

Photographs are reproduced showing the distortion of the cross-sections. These are treated in a quantitative manner, measurements of the ratio of distortion to increase in length being found for various reductions in area and angle of taper. The principal results obtained indicate that when an annealed wire is drawn through successive holes in a draw-plate, each of 3° taper, so that it suffers equal proportional reductions in area at each draught, the distortion of the cross-section rapidly diminishes until it has ceased to be measurable after four draughts. Further, that for any given reduction in area the distortion increases as the angle of taper increases. When the reduction in area is small and the angle of taper large so that the length of wire in contact with the draw-hole is small compared with its diameter, the distortion of the central part is independent of the angle of taper, but the distortion in the outer part increases as the angle of taper increases. It is also shown that for a given reduction in area and angle of taper the distortion in the outer part of the wire is greater when the drawing is done in two stages than when the whole operation is done in one draught. The distortion in the central portion is the same in the two cases. The fact that the distortion of the outer part of the wire varies so much with the angle of taper of the draw-hole, whilst the inner part is little affected, seems to explain why different X-ray analysts obtain consistent results for the structure of the inner parts of drawn wire, but widely divergent results for the outer layers.

Open-air Corrosion of Copper: Part III.—Artificial Production of Green Patina.

Previous work in this series* showed that the natural green patina on copper consists essentially of basic copper sulphate, except at the seaboard, when it is accompanied by more or less basic copper chloride. Arising out of this work the behaviour of copper in synthetic atmospheres containing various concentrations of sulphur dioxide and of water vapour has recently been investigated with particular regard to the mechanism whereby sulphate or basic sulphate is produced at the metal surface, and this is discussed in a paper by W. H. G. Vernon, D.Sc., Ph.D., F.I.C.

When once established the natural patina is highly protective; it has also a definite æsthetic value, which, however, is offset by the long period normally required for its development. Further, it has been confirmed that at relatively long distances from the town, and at much

* Vernon and Whitby, *J. Inst. Metals*, 1929, 42, 181; 1930, 44, 389.

shorter distances from the sea, the formation of green patina ceases. Methods have been worked out for the rapid production of an artificial patina, in order to eliminate the long period normally required for the development of the natural product. Investigations show that a green patina of basic copper sulphate may be obtained by treating the metal with a solution of ammonium sulphate preferably followed by application of a mixture in which basic copper sulphate is suspended. The coating breaks down under severe weather conditions, probably through physical causes. A patina that is stable under similar conditions is produced by an anodic treatment of 15 mins. duration in a suitable electrolyte ; it has a good green colour and is quite insoluble in water. On leaving the bath the deposit has the formula $CuSO_4.Cu(OH)_2$, but on exposure to the oper air a progressive increase in basicity takes place. It is believed that the composition of the coating will ultimately reach that of the natural patina after long exposure (previously shown to be $CuSO_4$.-$3Cu(OH)_2$).

Certain synthetic coatings other than basic copper sulphate, although initially green, readily blacken on exposure to town air. The application of linseed oil, and more especially of lanoline, to the primary coating gives marked protection to the underlying metal but does not prevent discoloration ; the application of water glass and of silicon ester, on the other hand, appreciably increases corrosion.

A Modified Impingement Corrosion Apparatus.

Many attempts have been made to devise tests for reflecting the probable service behaviour of a given metal by accelerating the corrosion above its natural rate, so that visible or easily measurable changes occur within a comparatively short period. Even if such tests do not accurately reproduce working conditions, they help in elucidating some of the phenomena associated with corrosion. With this object in view a form of jet impingement test has been devised, of which a full description is given in a paper by H. W. Brownsdon, M.Sc., Ph.D., and L. C. Bannister, M.Sc., Ph.D. The underlying idea consists in immersing a metal specimen in a corroding liquid and blowing air on to it by means of a jet made of drawn-out glass tubing. The main virtue of the method lies in the accurate control obtainable over the various factors which influence the special type of corrosion produced. The principle involved is not new and had previously been employed in experiments on the corrosion of resistant alloys by acids, but the value of the method for studying the phenomena associated with more general types of corrosion seems to have been overlooked. A few preliminary experiments with the apparatus showed that with several different alloys the types of attack produced were similar to those given with the May apparatus, and that a 500-hr. period of impingement sufficed for obtaining the necessary evidence regarding relative resistance to corrosion.

Some preliminary results obtained are given in the paper in order to illustrate the use of the apparatus in the study of corrosion phenomena.

Two Years' Corrosion Tests with Duralplat in the North Sea.

The registered material "Duralplat" comprises duralumin alloys which are coated with duralumin ; the base metal being a duralumin alloy containing copper with high tensile properties, while the coating metal is a duralumin alloy, containing magnesium and manganese, but no copper, with lower tensile properties, but with high resistance to corrosion. In the compound alloy Duralplat the coating layer is electro-negative towards the base alloy so that the latter is protected against corrosion also by an electro-chemical effect. The layer is not only harder and stronger than pure aluminium alone, but is also capable of age-hardening under the same conditions of heat-treatment and ageing as the base alloy.

Corrosion tests carried out on this material for a period of two years in the North Sea and the results are given in a paper by Dr.-Ing. K. L. Meissner. The specimens consisted of strips of four different thicknesses, drawn profiles of two thicknesses, and riveted strips. The results of the tests showed the excellent corrosion resistance of this material. Only one group of the thinnest specimens of 0·5 mm. thickness which were almost entirely under water for the whole time was found to be attacked in the interior so that the tensile properties were reduced to a serious degree. On the other hand, the base metal of strips of the same thickness which were only exposed at ebb and flow of the tide was not yet corroded ; in these the coating layer only was affected, hence they still maintained excellent tensile strength and elongation, so that this material could be used unhesitatingly, even after this period, for constructional purposes, though no further protection was applied, as, for example, by a lacquer or varnish. The life of thicker materials, especially of more than 1 mm., is undoubtedly very long.

The electro-chemical protection of the base alloy by the coating is so pronounced that no corrosion takes place in the base metal before the layer has entirely disappeared. Normal rivets are protected in the same way. The corrosion is practically confined to the parts of the coating under the heads of the rivets. In 18 months, however, no case was observed in which the rivets became loose owing to its complete disappearance.

The Properties of Commercial Varieties of Copper at High Temperatures.

Although much work has been published dealing with the tensile properties of copper at elevated temperatures, little information seems to be available regarding the impact strength, resistance to alternating stresses, and hardness at high temperatures of commercial coppers of known composition. It has been stated that there is a black, brittle range in copper. Instances had been mentioned of copper tubes which, after annealing, had broken if hammered when cooling through a black heat. The development of brittleness in a particular variety of copper, when cooling through a range of temperatures, would obviously show a low impact strength at that temperature ; and the production of brittleness by plastic deformation at a certain temperature, would seem likely to cause fracture within a short space of time, if subjected to alternating stresses exceeding the elastic limit. Tests of this nature were, therefore, carried out at various temperatures, and the results, given by T. G. Bamford, M.Sc., show no evidence of the existence of a black brittle range below 600° C.

The impact strength, as shown by the Charpy test, develops maximum values in the region 200°—340° C., after which it declines sharply. Except in the case of "tough-pitch" arsenical copper, which is weak at all temperatures above 400° C., quite good impact strength is, however, maintained at all temperatures up to 600° C.

Under alternating stresses exceeding the endurance limit generally speaking the nickel-copper has the greatest, and the "tough pitch" non-arsenical copper the least, endurance. There is in all cases a lowering of endurance in the region of 200°—300° C. The nickel-copper shows a marked recovery at higher temperatures, and is much superior to other varieties in this respect at all temperatures tested above 300° C. It shows an exceptionally high resistance to such stresses at 560° C.

The "tough-pitch" non-arsenical copper is, throughout the temperature range investigated, much softer than the other varieties of copper. The hardness of the deoxidised non-arsenical-copper first increases with rise of temperature and between 50° C. and 150° C. it is harder than any one of the other varieties.

Reviews of Current Literature.

The Heat-Treatment and Annealing of Aluminium and its Alloys.

It is doubtful whether more rapid progress has been made in any other metallurgical field than that which embraces aluminium and its alloys. The knowledge available in this section of metallurgy 20 years ago was very small and unreliable, but the change that has been effected since is remarkable, for it can be said that the phenomenal speeds that have been achieved on land and sea and in the air have only been possible as a result of increasing the power-weight ratio for which aluminium and its alloy are largely responsible. The development is the more noteworthy since it has emanated mainly from laboratory investigations, conducted primarily to improve the knowledge formerly existing on the subject. In the earlier investigations examples were discovered of alloys that proved to be susceptible to heat-treatment and a systematic study of the underlying causes led to the development of a large number of alloys which could be modified at will. It is this development that has been responsible for the amazing increase in the application of aluminium and its alloys.

The scientific principles underlying heat-treatment in this field are now better understood, and it is possible for the expert to determine which alloys are likely to be amenable to processes of heat-treatment and to indicate the most suitable form of heat-treatment necessary to confer required properties on these alloys. This degree of progress, however, has not been achieved without overcoming many problems encountered in the manufacture and application of the alloys: it has involved development of a new industrial technique, and a degree of pyrometric control in some instances previously considered almost impracticable.

Valuable information that has accumulated from investigations on the heat-treatment of aluminium and its alloys is somewhat scattered, and Dr. Budgen's primary object in this valuable text-book has been to assemble the knowledge available and present it in a useful form. The development made in the heat-treatment of aluminium alloys has been such as to leave no doubt that a special treatise on the subject is needed, and the author is very competent to deal with it from a practical, as well as a theoretical, viewpoint. He has outlined, in a condensed form, the main principles, practice, and progress to date of the heat-treatment of aluminium and its alloys in as simple a manner as possible consistent with the presentation of adequate practical and theoretical data for industrial application.

The author is to be congratulated in reviewing the work done so effectively and bringing it within a reasonable compass for practical application. The volume is divided into four main parts, and Part I. deals with wrought commercially pure aluminium. In the fully annealed condition wrought aluminium is slightly increased in tensile strength and hardness by heating to about 500° C. and cooling rapidly, but the extent of the increase of strength depends upon the purity of the metal. The effects of impurities and heating temperature are discussed, and the annealing of wrought aluminium is considered as well as its standard wrought forms and uses.

Commercially pure aluminium "as cast" undergoes some modification of mechanical properties as a result of various heat-treatments, although the amount is small, especially with regard to increase of strength, but data are given which show considerable increase in elongation. Published experimental data on this subject are not extensive, and thus Part II., which deals with that available, is somewhat brief.

Probably the most important section is that allocated to a consideration of the heat-treatment of aluminium alloys. The considerable improvement in mechanical properties by the application of certain heat-treating operations has led to the increasing use of these alloys. The fact that they can be hardened and strengthened, not only by cold-working, but also by heat-treatment and by a combination of the two processes has widened their scope of usefulness. This information and data on wrought alloys, given in Part III., is most comprehensive and valuable; it is subdivided, much space being allocated to increasing mechanical properties, while the softening of strain-hardened and age-hardened alloys are also considered.

Many "as cast" aluminium alloys are much improved by heat-treatment, and these form the basis for consideration in Part IV. The tensile strength, elongation, and hardness obtainable in some alloys by heat-treatment enable them to compete with forgings of such materials as brass, bronze, and mild steel.

The work includes a foreword by Dr. D. Hanson, and a number of appendices which deal with melting and alloying in the preparation of hardener alloys; corrosion embrittlement; mechanical properties of aluminium and various of its alloys at elevated temperatures; grain refinement; a standard colour scheme for marking heat-treated aluminium and its alloys; and the heat-treatment of aluminium-bronze; while the author has given a useful bibliography of workers who have made valuable contributions to the subject of the heat-treatment of aluminium and its alloys.

This is the first book to be published on this subject, and it should be in the hands of all who are associated with aluminium. The character of the text and the method of presentation will make it acceptable to both practical and theoretical workers, and there can be no doubt that, despite rapid progress which is being made in the field covered, it will become recognised as the text-book on this subject. The book, which contains 331 pages, is well illustrated, and its publication is a credit to the publisher as well as the author.

By N. F. Budgen, Ph.D., M.Sc. Published by Messrs. Chapman and Hall, Ltd., 11, Henrietta Street, London, W.C. 2. Price 25s. net.

Tables of Cubic Crystal Structure.

The aim of this book has been the collection of the available information, which has hitherto been scattered through the scientific journals of the world, in a convenient form. In each section the information is contained in the sets of tables, of which the first gives the substances in alphabetical order, with their chemical formulæ and index numbers in the succeeding table, and bibliography; the second gives the substances in order of lattice spacing and includes remarks, while the third is a full bibliography. It is of interest to note that the bibliography to the first section extends to more than 800 references, and that to the second contains 126 references. A useful feature is the inclusion of several pages for notes in extension of the work.

It is a useful reference book for those who practise X-ray methods of crystal analysis of powders and of separate crystals. Elements and compounds are dealt with by Dr. Knaggs and Dr. Karlik, while Dr. Elam has contributed a section on alloys. In a foreword, Sir William Bragg remarks, "The length of this summary is its own justification, for it shows how much searching of journals is required to discover whether or no any particular substance has been examined. . . . The authors will no doubt feel some satisfaction in realising that long researches by many workers have been rolled into one, and that they have earned the gratitude of those whose labour they have saved."

There can be no question that this book will be of the greatest assistance to workers in this field, and should go far to encourage the extended use of X-ray methods for chemical analysis by releasing for general and ready use information whose scattered distribution has rendered it difficult of access.

By I. E. Knaggs, Ph.D., B. Karlik, Ph.D., and C. F. Elam, M.A., D.Sc. Published by Adam Hilgir, Ltd., 98, Kings Road, Camden Road, London, N.W. 1. Price 11s. 6d. net.

Aluminium Sheet Production

By Robert J. Anderson, D.Sc.

Part XIV.—Cold-Rolling Mills.

In the present article descriptions are given of various types of mills which are, or may be, used for cold-rolling aluminium sheet and coil. Both the standard two-high and multiple-roll mills are considered. Rolls, bearings, and drives are dealt with briefly. Due to space limitations and the scope of the subject, the discussion is necessarily somewhat cursory.

VARIOUS types of rolling mills are, or may be, used for cold-working aluminium slabs, as delivered by a hot mill, into finished sheet and coil. Hitherto, the bulk of the production has been made with two-high units, but three-high mills have been employed to some extent—particularly for preliminary roughing operations. Three-high mills have been used rather more in Continental European plants than elsewhere. Some experimental work has been done of late to determine the performance and economic possibilities in cold-rolling aluminium on such multiple-roll mills as the four-high, cluster, and Steckel types. The indications are that these mills will all, ultimately, find their proper place in aluminium practice.

Cold-rolling mills for aluminium are built in various sizes and designs, depending on requirements, the preferences of operators, and engineering features as developed by manufacturers of special machinery. Details of construction for a given type of mill may vary considerably among the different builders. Sheet and coil mills for aluminium and its alloys are similar in structural design to those employed for other metals, more especially mills used for brass and copper rolling. Many factors may, and do, influence operators in the choice of mills for cold-rolling. Some of these include the following: The class of work to be done; the size of material to be processed; capacity required; gauge tolerances to be met; layout of the plant and available space; whether tonnage in a few sizes or small lots of many sizes are to be rolled; limitations as to capital expense; and whether mills are to supplement existing machinery in an old plant or are to be installed in a new works. Generally speaking, all-purpose mills are best adapted to the requirements of small plants unless only special classes of products are to be rolled, but in tonnage establishments various types of mills may be installed to advantage for processing different classes of stock. No type of mill is best adapted to all requirements, but the ordinary two-high non-reversing mill, equipped with rolls of moderate face length, is suitable for a variety of rolling purposes.

For convenience in discussion, cold-rolling mills may be classified as follows:—

1. Two-high sheet mills.
2. Two-high coil (strip) mills.
3. Two-high continuous mills.
4. Three-high mills.
5. Four-high mills.
6. Cluster mills.
7. Steckel mills.

These various types of mills are described in later paragr phs of this article. The double-duo mill is not ordinarily used for cold rolling, but could be employed for slabbing and roughing aluminium. Multiple-roll mills embrace the last four types listed in the above classification.

In practice, aluminium slabs for flat-sheet production are slabbed on two-high mills (reversing and non-reversing), three-high mills, and continuous two-high units. Roughing may be carried out on the same types of mills. Two-high, non-reversing mills have been used largely in American practice for slabbing and roughing. Three-high mills are well adapted for preliminary cold-working operations on large and heavy slabs. In some plants, these mills have found favour for slabbing and roughing stock of moderate width. Small slabs which can be easily handled by men can be processed faster on two-high, non-reversing mills than on three-high units. Two-high reversing mills, and two-high continuous mills (four to eight stands) are used for the preliminary cold-working of material in relatively narrow to moderate widths. Continuous mills have been used in the United States, and reversing mills have been employed rather more abroad. The continuous mill is

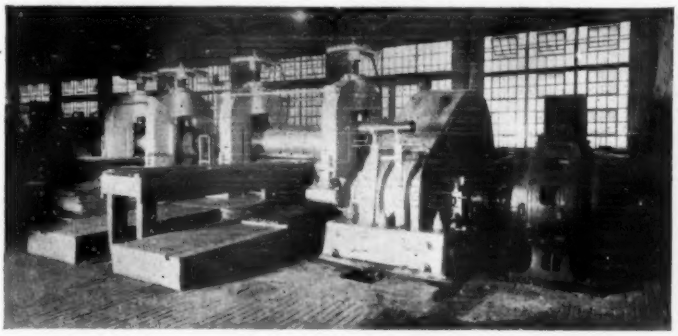


Fig. 1.—Two-high non-reversing sheet mills, used for slabbing and roughing.

indicated for use in tonnage operations. Slabs may be fed to it directly from a hot mill. Four-high and cluster mills, installed as separate units or arranged in tandem could, of course, be used for running down sheet slabs. So far, these types have been employed very little for any cold-rolling operations in aluminium practice. A four-high mill installation has, however, been made recently in an American plant.

Irrespective of the type of mill used for the preliminary cold-working, aluminium flat sheet is generally finish rolled on two-high non-reversing mills. In American plants two-high finishing mills for flat sheet are fitted with rolls measuring 48 in., 60 in., 72 in., and 84 in. face length. Some few mills are equipped with longer rolls. Four-high mills may find application for the finish rolling of aluminium and its alloys in the form of broad strip.

Aluminium slabs for strip and coil production may be roughed on the same types of mills used for slabbing sheet stock—viz., two-high (reversing and non-reversing), three-high, and continuous two-high mills. Ordinarily, such mills are equipped with rolls measuring up to 36 in. face length, but may be fitted with longer rolls. While the preliminary roughing of coil slabs may be done on the several types of mills just mentioned, the second and third roughing operations are to be carried out on mills which can be equipped with automatic winding devices for coiling the long lengths. The continuous two-high mill is well adapted to coil roughing. On a seven-stand continuous mill, hot-mill slabs ($\frac{3}{8}$ in. to $\frac{1}{2}$ in. thick) may be reduced to

about 0·1 in. thick in one operation, and delivered as coils ready for running down and finishing. In certain small plants, one or two single-stand two-high non-reversing strip mills are employed for all the cold-rolling operations on coil.

Aluminium coils are finish rolled on two-high strip mills; both the non-reversing and reversing types are used, and the former are more generally favoured. Automatic winding equipment is, of course, provided. Coil can be finished on four-high, cluster, and Steckel mills.

During the past ten to fifteen years, many important advances have been made in the design and construction of rolling mills. Demands for increased rolling speeds have had far-reaching effects. Housing, coupling, and drive structures are more rigid, better fitted, and made of stronger materials. Precision machine work is necessary in building the modern high-speed rolling mill. More efficient methods for lubricating roll necks have been developed to supplant the old practice of packing with grease. These methods involve the force feed of lubricant to the roll-neck bearings. As is known, satisfactory results with the four-high mill came with the application of roller bearings in place of the usual neck brasses. These bearings have also been used on two-high mills and other types, with important savings in power consumption and other advantages. Demands for better surface finish and closer gauge tolerances of sheet products have had marked influence on methods and details of mill construction. Close fitting in reduction units and couplings prevents back-lash and chattering, which, if present, have adverse effects on the material being rolled. Improved methods of grinding have been developed which yield exceptionally fine surface finishes on rolls. Production costs have been substantially lowered by the use of the latest types of mills. At the present time, plants equipped with older machinery are at considerable disadvantage as regards both labour costs and quality of product.

Two-high Sheet Mills.

Two-high non-reversing sheet mills are used extensively in aluminium practice for slabbing, roughing, and finish rolling in the production of flat sheet. These mills are of conventional design and are standard equipment in practically all plants. They are adaptable to a greater variety of rolling operations than any other types of mills. Drive may be by individual motor, but ordinarily a number of mills is coupled in a roll train. Two-high mills are equipped with rolls measuring from, say, 48 in. to 120 in. face length, the diameters being suitably proportioned to the lengths. At one plant in Germany there is a two-high non-reversing mill equipped with rolls 35½ in. in diameter by 131 in. long. This has been employed for both hot breaking down and cold slabbing. Two-high reversing mills have been used for the preliminary cold-working of sheet slabs. Two-high mills may be fitted with rolls shorter than 48 in. face length. In American aluminium practice, such mills having rolls up to about 36 in. long, are usually of the strip type.

The ordinary two-high non-reversing mill consists esentially of a pair of cylindrical rolls of the same diameter, suitably mounted one above the other, and a pair of housings. Bedplates may be of the unit type or consist of a pair of recessed rail-shoes. The unit type of bedplate is an integral cross-braced casting of sufficient length to carry the housings and pinion stand (and/or spindle support). Bedplates are bolted to suitable foundations. Housings are bolted to the bedplates, some adjustment being provided in the construction for roll length and roll changes. Bearing supports, bearings, and screw-downs are carried by the housings. The lower roll is mounted in a fixed position, and the upper roll is movable in a vertical plane, motion being transmitted by the screws. Movement of the screws may be effected by motor-drive through worms and gearing. Such drive is useful on slabbing and roughing mills, where the successive roll sets are appreciable. This should be supplemented by hand-actuated adjusting wheels. Hand-spanner wrenches are often used for screw adjustments on flat-sheet finishing mills where the roll sets are small and are made less frequently than on preliminary mills.

Materials of construction vary among different mill builders. Both grey cast iron and cast steel have been used for roll housings, pinion housings, bedplates, spindles, couplings, pinions, and miscellaneous structural parts. Steel is preferable to cast iron for structural parts, and is being employed by some of the leading builders. Fittings in general are made of forged steel. Rolls are generally made of chilled cast iron or of forged and heat-treated alloy steel. Screws are made of forged steel, and are bushed with hard bronze. Bearings are discussed in later paragraphs of this article.

As an example of sheet-mill construction, upwards of fifteen years ago, the following (taken from a catalogue of the Waterbury Farrel Foundry and Machine Co., Waterbury, Conn.) may be noted: The roll housings are made of charcoal iron, and are bushed through the top to form nuts for the screws, which latter are made of crucible steel. These screws bear on steel wearing pieces which rest on cast-iron riders. The upper roll and the parts resting on it are counterweighted by a system of rods, levers, and

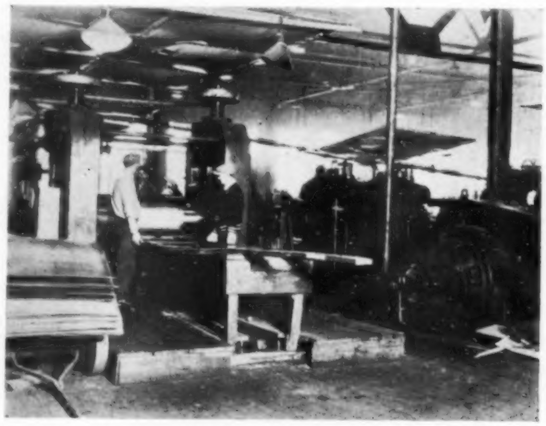


Fig. 2.—Two-high non-reversing sheet mill, operating on the finish rolling of grey plate.

weights hanging in a recess in the foundation. Pressure exerted by the weights is transmitted to the roll through bronze-lined lifters. The rolls rotate in bronze bearings, and are driven from the pinions through cast-iron spindles and couplings. These bearings are secured to the roll housings and riders, and are provided with ample means of lubrication. Pinions are made of cast iron, and have double helical teeth moulded from a pattern (which has machine-cut teeth). The pinion housings, boxes, and caps are made of close-grained cast iron, the boxes being babbitt lined. Cap bolts are forged steel, and the separators are steel. Both roll and pinion housings are bolted to cast-iron bedplates, the construction being such that the housings can be moved along the plates.

In later types of mills special precautions have been taken to eliminate vibration and noise caused in large part by inaccuracy of pinion fits, misalignment, incorrect clearances, poor lubrication, and unsupported spindles connecting pinions and rolls or two sets of rolls. Pinions, as well as gears in reduction units, should have machine-cut teeth to ensure accuracy. Spindles should be suitably supported—*e.g.*, by spring-cushioned arms to carry the weight and absorb shocks. Spindle-carriers are bolted to the bedplates, and the arms are provided with babbitted bearing surfaces on which the machined middle portions of the spindles rotate. Absence of vibration, chattering, and

(*Continued on page* 168.)

Standardising Foundry Pig Iron.

THE discussion in our last issue dealing with the above subject has resulted in considerable correspondence. This indicates that there is apparently general agreement with the view expressed that anything which would assist the producer to minimise the number of varieties of pig iron he has to supply would result in longer runs, more regular and uniform furnace conditions and, hence, better and cheaper pig iron with a smaller probability of off-grade iron. This desire is somewhat complicated, however, by the fact that many of the older furnaces still stack and supply to fracture. In doing this they are meeting the requirements of many users. It will, of course, be appreciated that the British founder attaches considerable importance to fracture—a method which has been demonstrated to have a scientific basis,—and many would regret the adoption of any system of grading pig iron wholly by analysis, as is now common in Germany and the United States. This practice is, however, increasing in this country, and some furnaces do stack mainly on analysis.

Under present conditions it seems that the founder has to deal with two antagonistic tendencies. He wants to buy as cheaply as possible, which, in the long run, means taking what the furnace has to offer. He also wants to buy to composition as nearly as possible approaching that of the metal he has to turn out, so that he relieves himself of errors and difficulties arising from the variable analysis of blast-furnace iron and the possibility of heterogeneity due to poor cupola melting. This explains the success of refined iron, in the making of which pig iron, to a greater or lesser extent, must be used.

It is evident from the opinions expressed that the interests of founders, blast-furnace men, and refined iron producers in this matter are rather conflicting. One of the most important difficulties in standardising pig iron is probably due to the fact that the present period is one of transition between grading by fracture and grading by a combination of fracture and analysis. The pig iron industry inevitably tends to supply what the buyer wants, thus any scheme of standardisation must begin with the founder, by endeavouring to persuade him to make use of what the furnaces can supply; in this way blast-furnace men will be encouraged to have longer runs with fewer changes.

Several correspondents agree entirely with the suggestion made in the article in question, and suggest that the Institute of British Foundrymen should discuss the matter with the object of simplifying production and reducing costs. Others think that the British Cast Iron Research Association could profitably take the matter up. In one instance the writer considers that the present position does approximate to that suggested in the article because the large furnaces with the big outputs, while they furnish an analysis, do not supply to guaranteed analysis other than that corresponding roughly to the fracture. Some opinions are expressed in the following selected correspondence which we believe will be of interest to our readers, particularly the suggestions that are made to effect some working basis for a further consideration of the problem.

Correspondence.

August 25, 1932.

The Editor, METALLURGIA.

Dear Sir,—I have read the article entitled "Standardising Foundry Pig Iron" with a considerable degree of interest, and, as a manufacturer, would welcome any steps that would tend to produce a standardisation of qualities, and which would be acceptable to foundrymen generally.

The situation would have to be approached with considerable care, as science has enabled considerable economies to be attainable in pig-iron manufacture under present-day conditions; on the other hand, scientific advance has also taught foundrymen the necessity for greater discrimination in the use of materials for the production of various specialised classes of goods.

This latter situation is to a certain extent responsible for the multifarious demands of foundrymen for varying grades of iron.

It will, therefore, be necessary to bear in mind the advanced requirements of the foundrymen and efforts will have to be made to endeavour to co-ordinate those requirements with those of the pig-iron manufacturer in order to prevent any unnecessary increase in costs.

The aim and object of the British Cast Iron Research Association has been largely directed towards finding out the best methods for obtaining the most perfect results in cast-iron manufacture, but these have not always been directed as to how the desired iron shall be produced, and specifications have been put forward which, whilst attainable at times accidentally in a blast furnace, are sometimes impossible of deliberate manufacture, possibly due—as mentioned in the article—to the high speed of working and modern design of furnace.

I think that the attention of the Cast Iron Research Association might be directed towards this aspect of the case, and that that Association should join forces with the Industrial Research Council of the National Federation of Iron and Steel Manufacturers with a view to seeing what can be done in this direction. By approaching the matter in this way the requirements of foundrymen could be safeguarded, and at the same time the difficulties of blast furnacemen could be appreciated and assessed at their proper value.

When one compares average British foundry practice with that existing in America and on the Continent, one is struck by the fact that in the latter two cases attention is usually directed towards analysis alone. In Great Britain there is a tendency becoming more and more pronounced to consider analysis to a greater extent than has hitherto been the case, but at the same time requiring it to be combined with the old method of classification by fracture, and in many cases a combination of the two becomes impossible from the point of standard blast-furnace practice.—Yours, etc.,

W. J. BROOKE
(General Manager).

Normanby Park Steel Works,
Scunthorpe.

September 2, 1932.

The Editor, METALLURGIA.

Dear Sir,—In my opinion there is no doubt whatsoever that if standardisation of pig irons could be brought about it would be a progressive and beneficial step to the foundry trade. It should, however, be made clear what implication is intended by the term "Standardising of Foundry Pig Iron." Broadly speaking, British blast-furnace practice has resulted in the production of three types of pig iron, namely: (1) Low phosphoric (Hematite); (2) medium phosphoric (Scotch); (3) high phosphoric (Cleveland).

Each of these types is procurable in numerous general grades, such as Nos. 1, 2, 3, 4, mottled, white, basic, etc., and also in special grades such as siliceous, cylinder, high-duty, mixed numbers, and anything else the pig-iron producer cares to call them. Quite obviously it is not the general type which requires standardising, but the numerous grades of each type, and one feels that this standardisation should be done by the pig-iron producer as part of his economic development programme. During the last ten years scientific developments in the foundries of this country have been beyond all precedent, and these developments have certainly helped in giving the progressive foundryman "his own ideas of what constitutes the most suitable pig iron for his needs." This statement, however, does not necessarily constitute or imply that the ideas are divergent, and my own impressions to-day suggest that the modern founder has a clear and unified conception of his requirements. No doubt the founder's requirements could be clearly placed before the pig-iron producers through the recently formed technical committees of the Institute of British Foundrymen.

One further comment calls for attention. Together with standardisation there is required new pig-iron developments, particularly the cheap supply of low-carbon hematites, or low-phosphoric irons, more suitable to the production of high-duty grey-iron castings. Prices of refined irons are in many cases prohibitive, and one notices more and more the tendency of the founder to employ high scrap mixtures, especially containing steel, together with special melting processes to produce his more important work. Will our blast-furnace plants soon be glorified dealers in scrap iron or competitors in the production of cheap castings?—Yours, etc.,

F. HUDSON
(Chief Chemist).

Glenfield and Kennedy, Ltd.,
Kilmarnock.

September 8, 1932.

The Editor, METALLURGIA.

Dear Sir,—Your article on "Standardising Foundry Pig Iron" in the August publication of METALLURGIA is one which calls for much thought in view of the many variable factors involved.

Since the introduction on the market of low-carbon pig iron, and, more recently, the superheated pig irons, the grading by fracture must, more than ever, go by the board.

For the same reasons it would seem difficult to adopt any useful grading without separating the purely "blast-furnace" product from the "high-duty" pig irons.

For the former where the phosphorus is largely controlled by the ore employed, no doubt a grading by silicon is best, and this might be limited to $\frac{1}{2}\%$ increments, leaving the skilled metallurgist in the foundry to use these according to his requirements. Under such a scheme it is doubtful whether the tolerances recently set up by the B.C.I.R.A. could be adhered to without intermediate "off grades" being left on stock. In most cases, however, under proper scientific mixing and control even intermediate grades could be equally well employed, and where such control was not in existence the pig-iron manufacturer might well find it worth his while to establish such a service for his customers' guidance. It is almost certain that "service" in this respect would result in an improved order book. It is to some extent this lack of technical control in the foundry that has resulted in the rigid demands in castings specifications being passed on by the foundry to the pig-iron manufacturer.

Pig irons produced in other than the blast-furnace are in a different category, for although all the components, including carbon, can be varied, as desired, with ease, the tonnages per melt are not so large. Here it would seem that a basis might be arrived at based on carbon, with phosphorus a secondary consideration, as a selective guide to each individual requirement. Silicon and manganese and other elements would then be called for as required.

Since the carbon variation affects the structure, in addition to providing a means of producing a lower carbon casting when high-duty is desired, this would seem a suitable basis to work on.—Yours, etc.,—L. E. DAWSON.

Sir W. G. Armstrong-Whitworth and Co. (Ironfounders) Ltd., Gateshead-on-Tyne.

September 9, 1932.

The Editor, METALLURGIA.

Dear Sir,—Your article on "Standardising Foundry Pig Iron" is a valuable contributon to a very important question. A review of past experience, however, indicates that foundrymen have for long years laboured in partial ignorance of the "make-up" of the pig irons upon which their success depended. The use of such knowledge, which they gathered from fracture, etc., is amazing and greatly to their credit, but it would appear that if the blast-furnace industry feel proud of their position to supply to analysis, it is only the outcome of these early and later foundry-workers clamouring for what they intuitively felt they had need.

The present position with its manifold specifications and limits of composition, so admittedly trying to the blast-furnace industry, is not an indication of any fancifulness in the mind of the foundryman, but rather the confirmation of the assimilation and application of knowledge on the one hand and the complicated designs and mechanical properties which have now to be met by the foundry.

If standardisation would be of such benefit to the blast-furnace operations, the query arises in the mind of the foundryman why this industry should not run their furnaces with two or three standard charges, and then, to meet the customers' requirements, instal suitable plant in the way of mixers, pulverised-fuel furnaces or electric furnaces, to enable them to alter the composition at will, according to their customers' wishes.

The door is wide open for the blast-furnace people to come down to the floor of the foundry and understand in a better and fuller way such difficulties as are encountered, which, in most cases, can only be overcome by a change in the composition of the iron.

Such foundries that can afford duplexing of melting are few and far between, but it would appear far more economical to treat the liquid metal from the blast-furnace for a correction to composition, than for the foundry to incur extra expense on an already improverished industry by remelting. The blast-furnace industry, in my opinion, could help to a solution of the problem if they were to send representatives from time to time who had a greater appreciation of foundry difficulties.—Yours, etc.,

W. WEST.

The Farington Steel Foundry,
of Leyland Motors, Ltd.,
Leyland, Lancs.

September 10, 1932.

The Editor, METALLURGIA.

Dear Sir,—I certainly agree with your article on "Standardising Foundry Pig Iron" that if any means can be adopted for minimising the very large variety of pig irons which iron-masters are called upon to produce for foundry purposes then undoubtedly a very great saving would be affected, but whether or not this would be reflected in the price demanded is quite another matter. It seems to me from the metallurgist's standpoint that there are in this country alone very many grades of pig iron which founders can call upon without making any special demands, unless for freak compositions, which generally, do not work out as expected when passed through the ordinary melting cupola, and thus the intended advantage of a definite composition is entirely lost by uncontrolled changes in the course of the melting; often with considerable excess of coke, and the consequent undesired pickup of carbon. For most classes of ordinary iron there is ample scope for the founder to select the grade he desires, by analysis, of course, and not by fracture, and adjust for his own melting methods the losses and gains achieved in melting. The old method of grading by fracture instead of analysis often led to the same grade being delivered with, for instance, silicon variations of 2% even in one brand, and unless this was determined and allowed for then serious trouble was invariably encountered. The matter is, of course, largely in the founder's hands, and I might finish by quoting from what I wrote over 20 years ago in "Principles of Ironfounding," that "the time is coming when brand names will be treated as of no importance, and when founders will be sufficiently familiar with the composition and resulting qualities of irons to be able to specify what they want, and to make sure that they get it, for it must be remembered that the iron masters can only live by supplying their customers with what they need, and therefore that a demand on the part of founders for any definite quality of iron—*i.e.*, a pig iron made to any given specification, must be met by the makers of the iron." I believe that in the several ways I have marked, this "time" is now in much more nearly general practice than when the prophecy was written—Yours, etc.,

J. S. GLEN PRIMROSE.

Chorlton-cum-Hardy,
Manchester.

Why Carburise So Much?

By W. F. Chubb, B.Sc.

In spite of great progress in heat-treatment furnaces and in metallurgy, old heat-treatment methods are still in operation, and the author discusses some problems a solution of which would result in reduced heat-treatment costs and benefit to both producer and consumer.

ONE of our most pressing needs under the present industrial conditions is that of reducing cost of production, preferably without lowering the standard of remuneration paid to either operatives or staff. Many progressive firms have made, and continue to make, advances in their production methods by the installation of improved machinery, and also by improved systems of handling materials. These and similar considerations have gone some way toward the attainment of their object, but it is a regrettable fact that many are much less ready to give serious thought to technical improvements in their heat-treatment operations. It is true that advantageous changes have been made in a few instances. Electric furnaces of high thermal efficiency have been installed and designed for most heat-treatment operations, and the healthy rivalry thus created has led to the introduction of gas furnaces of greatly improved design, technical control, and of much lower operating costs. Yet, despite all these changes of detail, the essential features of heat-treatment processes have remained the same, while rapid and continued advances have at the same time been made in metallurgical science and in our knowledge of the potentialities of materials. This may in many instances result from lack of direct access to metallurgical knowledge and thought, and in other cases perhaps to the inability from a number of possible causes of some development section or research department to convince the industry with which it is associated to make any desirable alterations to its existing methods of operation. Whatever the cause, the fact remains that heat-treatments are still being carried out by methods not essentially different from those employed by our forefathers. Certain changes in details have been made as a result of intensive metallurgical research, however, and a typical example of this is the carburising operation, which is used extensively as a means of securing a hard-wearing surface combined with a tough interior which will withstand shocks. In selecting material for any such component there seems to be a tendency to resort too readily to the carburising treatment, without due consideration of possible alternatives, and without due regard to the technical difficulties involved in that operation. A glance through the technical journals of the past three or four years will reveal that large numbers of contributions have appeared, specifically dealing with the technicalities of the procedure and at the same time giving in great detail accounts of the trials and tribulations of every metallurgist and case-hardener engaged in the process. The fact that each of these articles has attempted to enumerate alleged remedies for each practical departure from theoretical procedure clearly indicates that every recommended departure from standard practice results in opening up new problems. It is hardly necessary to remind those who are actively engaged in the carburising operation of the many difficulties which they encounter, but it might not be amiss to remind them of just one or two. In the first place, those carburisers who attempt to manufacture their own compound know the troubles resulting from inadequate mixing. Since the operation consists of heating for a relatively lengthy period of time at a high temperature, the cost must of necessity be somewhat higher than that of a directly hardening treatment, and although various modifications to the process are possible as a means of reducing operating costs, they are not infrequently accompanied by some sacrifice in another direction. The prolonged nature of the operation means loss of valuable time, and if for some reason the output from the heat-treatment department should become held up, there may be serious repercussions in wasting time in subsequent operations. From the standpoint, therefore, of the time occupied in carburising, the procedure represents a much lower standard of efficiency than can be attained in other heat-treatment operations. Quite apart from this question of time, however, there are other factors which offer support to the suggestion that methods can and do offer satisfactory alternatives. Among these may be mentioned the choice of carburising materials, its repeating qualities and mechanism of carburising, and other problems relating to rates of heating, uniformity of heating, and of temperature control, cementite formation, and prevention of brittleness, inaccurate treatment after carburising, and the relation between subsequent treatments and physical properties, are all considerations which lead one to inquire whether after all the trouble involved in securing the desired results is really worth the cost.

The realisation of these numerous disadvantages and difficulties naturally leads to inquiry into possible alternative treatments, and in considering this aspect of the problem several essential features are brought into mental review. Not the least important of these are questions of costs, service conditions of each part and component, and causes of failure. Now, the carburising treatment being one in which the treated material is given hardening power by an indirect agency must of necessity be more costly than a directly hardening treatment suitably chosen to convey the required physical properties, and this additional treatment may provide, and not infrequently does provide, the cause of many service failures. In choosing our alternatives, we are thus led to inquire into the most common causes of failure in case-hardened materials. Consider for a moment a few components almost invariably hardened by the process—*e.g.*, gears, camshafts, and worm-shafts. In seeking the causes of failure in gears, the author has found that most fail in shear, apart of course from those due to inaccurate treatment, and this is to be expected from the very condition of service. Few gears actually fail through lack of ductility in the core, and this has become recognised within recent years, and alternative steels have been adopted in their manufacture. As shear strength follows, at least to some extent, the hardness of the steel, the soft steels formerly employed have since conceded place to those of higher tensile strength, and oil-hardening nickel-chrome steels of 100-ton core strength, as well as steels for carburising, having 90-ton core strength, have gained ground in use. Yet each of these suffers from some disadvantage. The 100-ton oil-hardening nickel-chrome steel is expensive, although it may meet other conditions, and the 90-ton steel suffers from the necessity of carburising it to secure the requisite surface hardness. In camshafts, very few failures which the author has had occasion to investigate have resulted from lack of ductility in the material. Given suitable support under the highest compression loads imposed, there is, indeed, no reason why failure from such

a cause should arise, and it can with safety be asserted that the majority of failures in camshafts arise either directly or indirectly from the need to carburise and carburise deeply. Now this necessity arises from two causes. The first is, of course, that of imparting a surface possessing a very high degree of hardness, about 90 to 95 scleroscope, and to the need for increasing the rigidity of the core. That this increased rigidity and yield ratio can thus be secured has already been emphasised in the results of investigations and extensometer tests published earlier by the author in Metallurgia. At the same time, it was indicated that while advantageous use could be made of this influence, there were certain limitations which must be considered. The much-despised martensite-ferrite structure was also shown to possess all those physical properties desirable in a camshaft, since it was possessed of structural rigidity and resistance to shear and compressive stresses. The problem in this instance thus consists of choosing materials capable of giving a wear-resisting surface and having at the same time sufficient ductility combined with high resistance to torsional stresses. The author suggests that this can readily be secured without resort to a carburising treatment.

From the above considerations, the author suggests that modern service conditions do not require the property of high-core ductility obtainable by carburising treatments, and that the process can now only be regarded as uneconomic since the desired physical properties in any material can be much more cheaply secured by the correct choice of alternative materials and treatments. As an indication of desirable changes, certain examples have been taken from engineering practice, and the required physical properties have been considered in relation to choice of materials and possible failures. The problems presented are by no means easy of solution, but careful study of service conditions should point the way to technical improvements, resulting in reduced heat-treatment costs and benefit to producer and consumer alike.

Personal.

Mr. J. S. G. Primrose has been appointed deputy convener of the Technical Committee and convener of the Non-ferrous Metals Sub-Committee of The Institute of British Foundrymen.

Dr. W. Rosenhain, F.R.S., past-president of the Institute of Metals, has been appointed an honorary member of the Deutsche Gesellschaft für Metalkunde.

Dr. Harold Moore, C.B.E., who has for many years been director of metallurgical research at the Research Department, Woolwich, has been appointed as from October 1, 1932, director of the British Non-ferrous Metals Research Association, to succeed Dr. R. S. Hutton, who has been elected to the new Goldsmith's Professorship of Metallurgy at Cambridge University.

Mr. S. P. Hewitt has been appointed General Manager of Edgar Allen and Co. (Canada), Ltd., 116, McGill Street, Montreal. Mr. Hewitt will be responsible for the conduct of the entire Canadian business, including sales. Mr. J. K. Schofield will remain secretary and treasurer to the Company, while Mr. G. E. Membery will continue to be in charge of the Toronto branch of Edgar Allen and Co. (Canada), Ltd., and will act as sales manager.

A. C. Wickman, Ltd., machine-tool specialists, Coventry, have been appointed agents in Great Britain and Ireland for Birmingham Electric Furnaces, Ltd., manufacturers of "Birlec" furnaces, who recently entered into agreements with the Electric Furnace Co., Salem, Ohio, U.S.A., and C. I. Hayes, Inc., Rhode Island, U.S.A., for the fullest exchange of information and designs.

ALUMINIUM SHEET PRODUCTION

(*Continued from page* 164.)

backlash is essential in aluminium-sheet mills if satisfactory results are to be secured.

A few illustrations are shown in the accompanying photographs which serve to give an idea of two-high sheet mills as used in aluminium practice. Fig. 1 shows a pair of two-high, non-reversing mills used for slabbing and roughing operations on flat-sheet stock. The pair of mills is coupled together. At the right is the motor-drive and reduction-gear set, and at the left is the pinion stand. A spring-cushioned spindle-carrier may be seen between the two stands. The near mill was equipped with rolls measuring 26 in. in diameter by 84 in. face length, and the far mill had rolls measuring 24 in. in diameter by 60 in. face length. Counterbalancing of the upper roll of the larger mill was by means of weights and levers, and of the smaller mill by means of springs. The mills shown in this illustration are of a rather old type, but have given satisfactory service for preliminary cold-working operations. (In Fig. 3 of a previous article in this series, the opposite side of this mill installation is shown.[1]) Fig. 2 shows the catcher's side of a two-high mill being used for the finish rolling of grey plate. The driving motor is seen at the right; this is coupled to a reduction set, which in turn drives to the pinion stand seen behind the motor. Two mills are coupled to this drive. (The opposite side of this mill is shown in Fig. 4 of a previous article.[2]) Fig. 3 shows the catcher's side of a large two-high mill being used for the finish rolling of bright flat sheet. The rolls are 84 in. face length. This mill is one of two coupled to the same drive. (The opposite side of this mill is shown in Fig. 3 of a previous article—Part XIII.[3]).

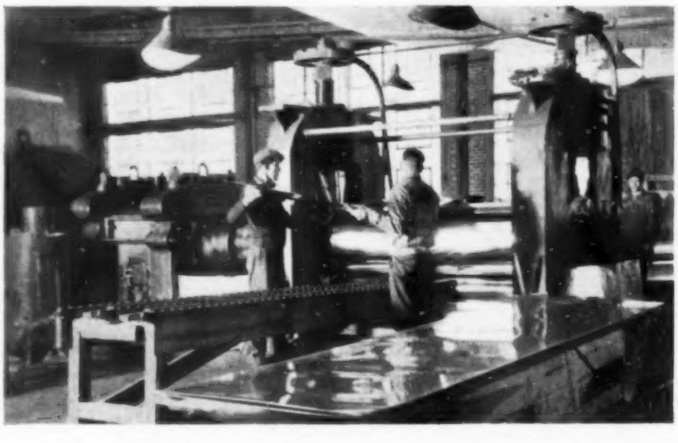


Fig. 3.—Two-high non-reversing sheet mill, operating on the finish rolling of bright flat sheet.

Roll speeds of two-high sheet mills vary in the range of about 24 to 38 r.p.m. The speeds are necessarily limited by the facility with which men can handle the pieces. For rolls 28 in. in diameter speeds of 24, 29, and 34 r.p.m. are equivalent to peripheral speeds of 176, 213, and 249 ft. per min. Higher speeds may be run on two-high reversing mills used for roughing and running down, where mechanical methods of handling are provided.

(*To be continued.*)

The British Commercial Gas Association, in co-operation with leading manufacturers, has arranged a display of the latest domestic gas appliances at the Building Centre, 158, New Bond Street, W. 1. These appliances are placed in separate sections in order that the architect, builder, or other visitors can conveniently inspect them.

1 R. J. Anderson, "Aluminium Sheet Production. Part XII.—Slabbing and Roughing," *Metallurgia*, vol. 5, No. 29, March, 1932, pp. 162.
2 R. J. Anderson, "Aluminium Sheet Production. Part XIII.—Finish Rolling," *Metallurgia*, vol. 6, No. 32, June, 1932, pp. 48.
3 R. J. Anderson, *loc. cit.*

Recent Developments in Tools and Equipment

A Special Extension-type Vertical Boring Mill.

THE rapid development of high-duty alloys presents difficult problems in their machining, and in order to cope with these problems various cutting materials have been developed with remarkable success, but it is recognised that machine-tool improvements are also necessary to obtain the most satisfactory results. In addition to modifications in the designs of machine tools to make effective use of modern cutting materials, modifications are frequently necessary to permit the economic machining of special types of work; an excellent illustration of this is indicated by the vertical boring mill recently built by George Richards and Co., Ltd., of Broadheath, Manchester, and supplied to Messrs. J. Stone and Co., Ltd., of Deptford, London. This machine is a modification of a standard type, and has been designed primarily for machining the bosses of all types of propellers ranging in size up to 25 ft. in diameter. The long and specialised experience in propeller work, coupled with the difficulties encountered in machining the special bronzes used in this class of work by Messrs. Stone, has enabled this firm to render useful assistance to the builders in the design of details incorporated in the machine.

The machine is designed for dealing with the larger sizes of ships' propellers, and the work it performs includes: Sawing off the head of the rough casting, facing up both fore and aft of the boss, boring out the boss and cutting the keyway; all this is accomplished without removing the propeller from its table. This is of particular interest in view of the fact that the material to be machined is frequently a special high-tensile bronze, which has been developed by Messrs. Stone's after extended metallurgical study, and is known as "Turbiston Bronze." The mechanical properties of this alloy are: Elastic limit, 16–18 tons per sq. in.; tensile strength, 32–46 tons per sq. in.; elongation on 2 in., 20–30%; Brinell hardness, 120–140; specific gravity, 8·2–8·3.

As will be noticed in the illustration of this machine, Fig. 1, only one swivel head is fitted on the cross-slide, while a centre head of special design is also fitted. The swivel head performs the slotting operation and the centre head the sawing, boring, facing, and recessing operations on the propeller. During the whole of these operations the table, to which the propeller is securely clamped, remains stationary. This is contrary to the usual procedure in vertical-boring mill work, in which the table with its load revolves; it is of interest to note, however, that all the necessary mechanism is included to enable the machine to be used as an ordinary boring mill when desired.

The centre head is of heavy proportions, and embodies a spindle of large size and ample strength for driving a 6-ft. diameter saw, boring bars, and facing arms. The drive to the spindle is by means of either a high ratio worm and wheel for sawing and large facing operations, or a low-ratio worm and wheel for the boring operations, the change being effected by the movement of a lever on the centre head. These worm-wheels are of centrifugally-cast phosphor bronze, while the worms are of $3\frac{1}{2}$% nickel steel, case-hardened and polished; they are continuously lubricated with a copious supply of oil from a plunger pump, which forms an integral part of the saddle carrying the centre head. The final drive to the spindle is by means of a double-helical steel pinion mounted on a high-carbon steel multi-spined shaft, and a double-helical wheel mounted directly on the spindle.

The spindle speeds range from 6 to 93 r.p.m., and are obtained as follows: The gearbox for driving the centre head, which, together with its 30 h.p. motor, is mounted on the left-hand end of the cross-slide, provides two mechanical changes, while two alternative changes are available on the centre head itself. These, together with the use of a rheostat controlling the 2-to-1 variable speed motor, enable any desired intermediate speed between 6 and 93 r.p.m. to be obtained. The drive from the motor to the gearbox is by laminated gears.

The first operation on the propeller boss is the sawing-off of the riser, and this is performed by the 6-ft. diameter saw with inserted segmental teeth. The saw runs at a peripheral speed of 111·5 ft. per min., the feed of the saw being obtained by traversing the head along the cross-slide, and the rate of feed varies from $1\frac{3}{4}$ in. to 6 in. per min. by means of change-wheels. It is interesting to note that the horizontal feed of the centre head when sawing is quite independent of the spindle speed, but varies with the motor speed. The riser is sawn off at four cuts, and

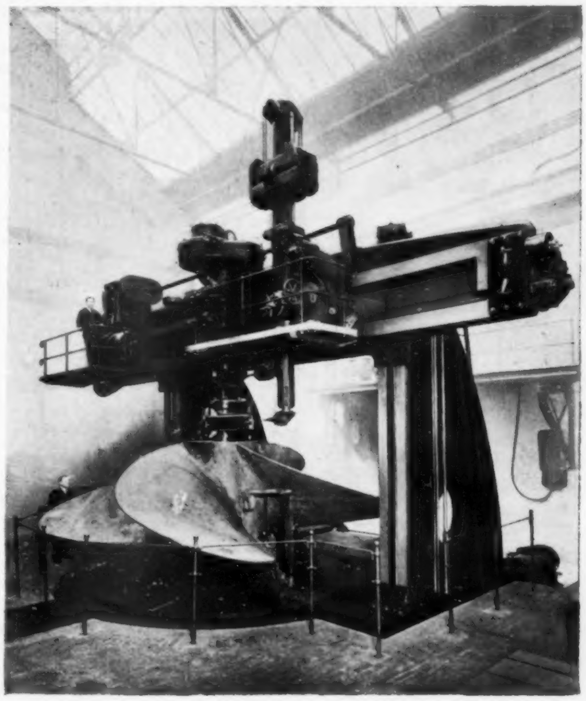


Fig. 1.—A general view of the boring mill in operation machining the face of a large propeller.

index lines are provided on the periphery of the table for convenience in spacing for each cut; wedges are driven into the saw cuts to prevent the head nipping the saw.

On completion of the sawing operation, the riser is lifted off and the boring and facing operations commenced. The boring-bar is first of all carefully centralised by means of the rule and vernier on the driving slide to the boring bar—the bottom end of the bar being keyed to and guided by a ball-joint in the centre of the table. The hole in the boss is first rough-bored parallel. It is interesting to note that "Widia"-tipped tools are used for the rough boring operations. Several cuts are taken by this head, which has continuous automatic feed, until a diameter about $\frac{1}{2}$ in. less than the small end of the finished taper bore is reached, when the head is removed and another head for step-boring mounted on the bar.

By means of the second head, which also has continuous automatic feed, a series of steps are bored through the boss, adjustment to the tools for the different diameters being provided on the head itself by means of a graduated dial. The depth of each step of the bore can be settled beforehand and a special depth control mechanism is fitted. This consists of a large graduated dial geared to the main spindle and provided with adjustable pointers which can be set to correspond to any given depth of bore, and one revolution of the pointer round the dial is equivalent to a continuous down feed to the boring head of 6 ft. For any intermediate length of step to be bored the pointer is set to read accordingly on the dial, and when zero on the pointer and dial coincide, the feed to the head is automatically stopped by the action of the small limit switch.

For the operation of taper-boring, the bar is first swivelled over the desired mount—this being accurately recorded by the rule and vernier on the driving slide—and firmly locked in position. The taper-boring head is then fed through the boss until the hole is correctly finished to size. Here again continuous automatic feed is provided to the boring head. The drawing, Fig. 2, clearly shows the procedure adopted for this operation.

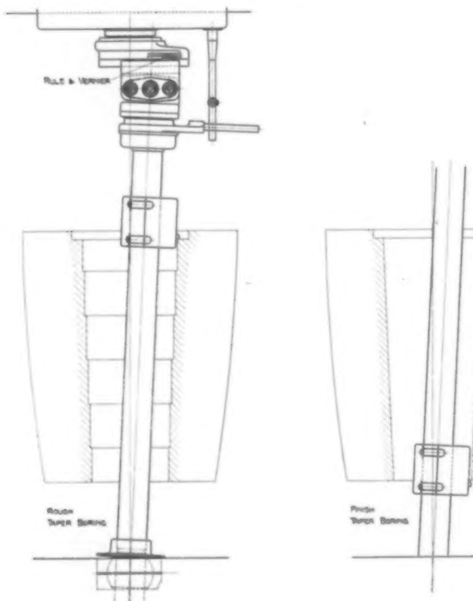


Fig. 2.—Arrangement for taper-boring the boss.

When the boring and facing operations are completed the centre head is traversed to the left-hand end of the cross-slide, and the right-hand or slotting head brought into position. This head in all essential features is an ordinary swivel-head as fitted on a standard boring mill, and the ram is balanced by a weight sliding on the column. The ram has a maximum stroke of 7 ft., variation of which is effected through a dial on the end of the cross-slide.

In some propellers the keyway is tapered on the sides, and for dealing with this a special attachment is necessary, consisting of a former bar swivelled perpendicular to the cross-rail and clamped to a bracket on the saddle, also to a bracket on the table, these two brackets providing the necessary adjustment to the former bar for giving the side taper required. The tool is carried in a special tool-holder, which receives its side-tapering motion through a roller which works in a slot in the former bar. The operation is then carried out in exactly the same manner as for parallel keyways.

The lubrication of the machine has received very special attention. For all the bearings on the lower part of the machine, including the main spindle and table bearings, two mechanical forced feed-pumps are fitted. These provide a continuous supply of oil, and require no attention on the part of the operator. All other parts to be lubricated are cared for by power or hand-feed pumps, several of these being conveniently placed at different points, and each supplying oil to a number of bearings, gears, etc.

The whole of the sliding units are moved by power, there being no less than six motors incorporated in the machine as follows :—

1. For raising and lowering the cross-slide and rapid traverses to heads. (15 h.p.)
2. For driving the slotting ram. (15 h.p.)
3. For driving the centre boring head. (30 h.p.)
4. For moving the uprights backwards and forwards. (10 h.p.)
5. For turning the table round for spacing purposes during sawing, and when two or more keyways have to be cut. (10 h.p.)
6. Rapid return to boring head on boring bar. ($1\frac{1}{2}$ h.p.)

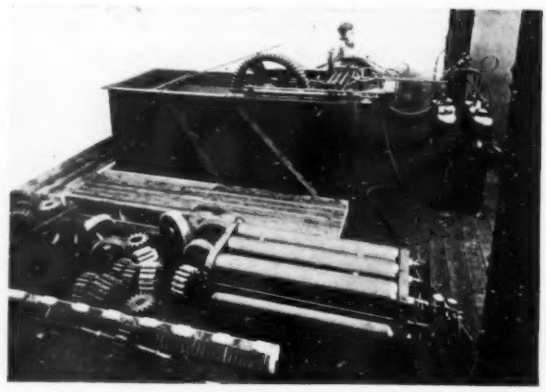
When used as an ordinary boring mill, No. 5 motor is substituted by one of 50 h.p.

All these motors have push-button control, which enables any of the motors to be controlled from a number of convenient points on the machine.

As some of these propellers weigh over 50 tons in the rough, in which condition they are placed on this machine, the table and table bearing are of very robust construction. The table-spindle is also of large proportions, and of ample rigidity to stand up to the heavy duty involved. It will be realised that the machine throughout is of very large proportions, the net weight being approximately 152 tons. The following dimensions of the machine will also be of interest : Extreme height from floor level, 28 ft. 4 in. ; extreme width, 35 ft. 6 in. ; extreme depth, front to back, 28 ft. 1 in.

Shorterising Parts Subjected to Excessive Abrasion.

THE "Shorter" process of hardening, as pointed out in previous articles, is effected by mechanically operating an oxy-acetylene flame suitable in size and degree to the area under treatment, over the surface to be hardened, and following this with a cooling jet to quench the heat imparted to the surface. This cooling jet follows immediately behind the heating flame, as it traverses the surface of the metal, so that quenching takes place immediately the steel is brought to the critical temperature. A machine for this purpose is built by the Patent Gear and Metal Hardening Co., Ltd., 69, Horseferry Road, Westminster, S.W. 1, which is designed with the object of simplifying the process and to give a high degree of control.



New machine designed for simplifying the process of shorterising.

A new machine recently installed in the Darlaston works of Messrs. The Wellman Smith Owen Corporation, Ltd., is the largest that has yet been made, and is capable of hardening gears up to 7 ft. 4 in. diameter, 24 in. tooth face, and pitched from ⅜ in. circular pitch to 4½ in. and more if required. Special facilities have been provided for dealing with a variety of articles, so that areas can be locally hardened at points where excessive abrasion is likely to occur on heavy machinery parts.

This machine, which is shown in the accompanying illustration, has many improvements over the machine previously described. These improvements relate in particular to facilitating and simplifying operations. The heavy and cumbersome head which was incorporated in the design of the old machine has been dispensed with by the introduction of a light carriage worked on parallel-bar slides. In addition, adjustable sides have been fitted to the tank in order to facilitate the hardening of some particular heavy work which will be submitted to the process at these works.

The illustration shows two batteries of cylinders, that on the right of the machine being a twin battery of three, each containing dissolved acetylene, so arranged that operations can be continuously carried out throughout the whole day without any change of cylinders. The battery of standard oxygen cylinders in the front of the machine is arranged to give a continuous feed of oxygen to the machine in order to reduce the amount of changing that has hitherto been necessary when handling single cylinders.

The Wellman Smith Owen Engineering Corporation will not only harden gears and other parts manufactured in their own works, but will undertake work for their clients in the vicinity. Quite a number of Shorterising machines are now operating under licence, amongst which may be mentioned those in the works of Messrs. R. Hoe and Co., Ltd., London ; Messrs. R. W. Crabtree and Sons, Leeds ; and Messrs. David Brown and Sons, Ltd., Huddersfield, while large operating depots have been opened in London and at the British Oxygen Co.'s Trafford Park depot, Manchester, large quantities of gears have been treated by this process.

Photo-Electric Control Equipment in Tube Mills.

THE process of manufacturing welded-steel tubes requires very rapid handling of the hot steel strip from which these tubes are rolled, right from the moment when the heated strip is pulled out of the furnace with a temperature of over 1,350° C. to the end of the process, when the finished tube moves down the cooling rack at the other end of the tube mill plant.

Tubes of this description are usually 15 ft. to 18 ft. in length, and the time interval between the rolling of the tubes in the most up-to-date process is a matter of a few seconds. The tube, after it has passed through the sizing rolls, runs at a considerable speed down a trough, and is automatically transported to the cross rolls for hot straightening. After it has passed the cross rolls it moves on to a cooling bank, dropping into a collecting cradle, whence it is taken away in bundles by means of overhead transporters to the finishing shops for cutting into lengths, testing, screwing, etc., before it goes into the warehouse for despatch.

Owing to the rapidity with which the tubes follow one another through the sizing rolls and the cross rolls, the operation of releasing the tubes from the cross rolls to the cooling bank is one which demands constant watchfulness and prompt action on the part of the operator. This will be realised from the fact that the distance between the tail end of one tube and the nose of the next following tube is often only about 3 ft. The slightest error in timing by the operator will result in a temporary stoppage, due to collision between the tubes. Mechanical means to check these operations and to prevent the tubes from colliding or being sent forward into the cross rolls before the preceding tube had cleared it, have failed. The reason for the failure was that any lever or electrical appliance that was struck by the hot tubes travelling at a great speed in rapid succession, wore out or was damaged by the impact within a very short period of time.

The whole matter was investigated by the General Electric Co., Ltd., with a view to developing photo. cell equipment for carrying out these operations efficiently, and recently equipment of this kind has been introduced into the works of Messrs. Stewarts and Lloyds, Ltd., the well-known tube manufacturers. It was found that the ray given out by these hot tubes will operate a photo. electric cell placed within a few feet of the tubes as they travel from the sizing rolls through the cross rolls to the cooling bank. The current set up in the photo. cell is amplified through an Osram valve, and relays to operate an electrical contactor, which closes the circuit of a powerful solenoid. By means of the solenoid, the releasing shutters, which were originally operated by hand, are automatically operated at exactly the right moment, and by this means collision of tubes is prevented.

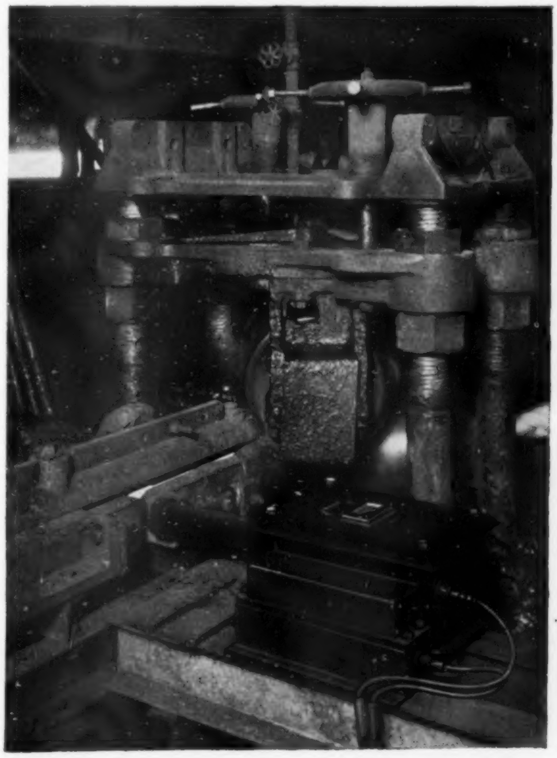


Photo-electric control apparatus used in tube-rolling mill.

At the same time, each tube is counted in a similar way by means of its ray being picked up by another photo. cell equipment which operates a solenoid-operated counter. Further, optical warning signals, consisting of red and green lights, are installed to indicate to the men at the furnaces and the racks when the line is safe for sending along another tube, or when the passage is blocked.

Provision can also be made, when desired, to test the actual temperature of the hot strips when leaving the furnace, or of the tube at any time of its travel, by means of photo.-electric temperature recorders.

The apparatus is simple, but particularly strong and robust in construction, so that it can stand the onerous conditions existing in tube rolling mills, including the high temperatures and the great vibrations set up in the plant. It is of interest to note that this photo. cell equipment will operate directly from either an A.C. or a D.C. circuit.

Business Notes and News

Redundant Shipbuilding Capacity.

There are few industries which possess so much redundant capacity as that of shipbuilding, and with huge numbers of vessels already laid up there is ample reason for the adoption of some scheme for reducing the building facilities for more vessels. The Baltic and International Conference have taken the matter up with a view to ascertaining the opinions of Continental shipbuilders to this end. The Conference emphasises the fact that the world's present capacity is far in excess of any possible future demand. It is pointed out that ships are now built in much less time than before the war, and it is feared that, should a flood of orders follow an improvement in freights, all of which could be absorbed by the various yards in different countries, shipbuilding firms could neither expect to earn reasonable profits nor enjoy a period of continuous employment until the facilities for building ships are reduced to a point where they will approximate more nearly to the normal demand.

It will be remembered that action was taken in this country some two years ago by the National Shipbuilders' Security, Ltd., the main purpose of which was to eliminate redundant yards, and productive power has been considerably reduced as a result of the efforts of this organisation. Whether such methods can be adopted in foreign countries, in many of which State support is given, remains to be seen. It seems that the abandonment of the policy of subsidies will be necessary before the industry can be adequately organised and restored to a condition in which prosperity will be more easily restored.

British Trade Exhibition in Copenhagen.

Danish traders are of the opinion that steps should be taken to put their trade with Britain on a more reciprocal basis. Our Government have been approached with a request to open negotiations for a trade agreement, and they have organised a "Buy British" movement which has culminated in the British Trades Exhibition in Copenhagen. Great Britain is Denmark's best customer, and her trade is the main source of the prosperity of this Scandinavian country. The steady demand for Danish agricultural produce has created an important industry, which has made the country one of the most prosperous in Europe. Although somewhat belated this attitude cannot but lead to better trade relations between the two countries, particularly if, as is desired, the Danes take our coal, iron, and steel and engineering products and manufactured goods on a more reciprocal basis. The Trade Exhibition which is to be opened by the Prince of Wales on Sept. 24, is one of the largest wholly British efforts to be held in a foreign country, and, in view of the new attitude adopted in regard to British goods and products, it is likely to be very successful.

Survey of Large Coal Seam.

The vast resources of the Brockwell coal seam in Durham are stressed in a survey of the seam published recently by H.M. Staionery Office. This seam outcrops in the west of the area along a north and south line through Mickley, Blackhill, Tow Law, and Witton-le-Wear, and in the south from Cockfield eastward to Shildon; from here to the coast the southern outcrop is concealed beneath a cover of newer rocks.

Just south of the Tyne the seam is very persistent, and has an average thickness of 3 ft. 6 in., gradually thinning to the east. In the north-west corner of the area, from Mickley to Enchester, a layer of coal about 12 in. thick occurs below the Brockwell seam, from which it is separated by clay.

There is, in the central parts of the Durham coalfield, an area over which the seam, although yielding a high-grade coking coal, is thin and poorly developed. This area lies east of the river Derwent, and is bounded by Pelaw and Burnopfield in the north, and Durham and Consett in the south.

Approaching its southern outcrop the seam attains its maximum development, reaching a thickness of 7 ft. 7 in. in the neighbourhood of West Auckland, but the character of the coal changes. The content of volatile matter becomes higher, and it is extensively used for gas manufacture, steam raising, and as a domestic fuel in the south, as well as for cooking purposes. Throughout Durham this seam produces one of the most valuable coking coals.

Trade with Russia.

It is fully expected that the further consideration which has been given to export credits will lead to further Russian orders being placed in this country. It is not fully recognised how important is this country's trade with Russia. The figures given recently by the Board of Trade are very convincing. During 1931 the total exports of machinery were valued at £4,417,907, as compared with a total of £19,288,381 from all foreign countries combined. France took machinery to the value of £2,050,893, or less than half the amount bought by Russia. The trade is carried on by a system of long-term credits guaranteed by the Government, and the difficulty in obtaining these guarantees was disturbing manufacturers.

The Manchester and Salford Trade Council pointed out that during recent months Soviet orders to the value of £3,000,000, which were first offered to our engineering and electrical firms, were subsequently transferred to other countries because the Government refused to provide the necessary quarantees. It is hoped that greater assistance will now be given to British manufacturers who are desirous of accepting Russan orders, though it is feared that much-needed work will have gone elsewhere.

Recent Launches.

H.M. Submarine *Porpoise* was launched at the Naval Construction Works of Vickers-Armstrongs, Ltd., at Barrow-in-Furness by Lady Fuller, the wife of Admiral Sir Cyril T. M. Fuller, K.C.B., C.M.G., D.S.O., Second Sea Lord and Chief of Naval Personnel. This is the 161st submarine launched from the Barrow shipyard.

H.M.S. *Achilles* was launched from the Birkenhead Yard of Cammell-Laird and Co., Ltd., by Lady Stanley, wife of Lord Stanley, the Parliamentary and Financial Secretary to the Admiralty. This vessel has a main length of 520 ft., with a beam of 52 ft. 2 in., and at the mean draught of 16 ft. her standard displacement will be about 7,000 tons. The shaft horse-power to be developed by turbines will be about 72,000, estimated to give the cruiser a speed of 32·5 knots.

The new quadruple-screw turbo-electric liner *Queen of Bermuda* was launched at the Naval Construction Works of Vickers-Armstrongs, Ltd., at Barrow-in-Furness, by Lady Cubitt, the wife of His Excellency Lieut-General Sir Thomas Astley Cubitt, the Governor of Bermuda. This vessel, which has been built for the New York-Bermuda services of Furness, Withy and Co., Ltd., has a water-line length of 576 ft., with a breadth of 76 ft. 6 in., a depth to C deck of 43 ft. 3 in., and an estimated tonnage of 22,500 gross. Her propelling machinery will comprise a quadruple-screw arrangement of two turbo-alternators and four propelling motors, designed and built by the General Electric Co., Ltd., and Fraser and Chalmers Engineering Works. The total output of the propelling motors will be 19,000 s.h.p., and there are to be two 10,000-h.p. turbines running at 3,000 r.p.m., driving two 7,500 kw. alternators, which will supply current to four 150 r.p.m. propelling motors. Steam will be raised in four high-pressure Babcock and Wilcox water-tube boilers, designed for 400-lb. pressure, with a superheated steam temperature of 650° to 675° F. The auxiliary machinery will include Weir regenerative condensers and auxiliary pumps.

Steel Enquiry.

Satisfactory progress is reported with the work of the National Committee appointed at the request of the Import Duties Advisory Committee, to prepare a scheme for the reorganisation of the iron and steel industry. Although some difficult problems have arisen and varying points of view necessitate adjustment, it is understood that eventually general agreement will be reached. It is fully expected that by the end of the present month a report will be presented to the Advisory Committee showing in detail the work which has been done.

It is confidently expected to convince the Imports Duties Advisory Committee that the duties on steel products should be continued and to submit a reorganisation scheme that will meet approval. Considerable spade work has been done and the result of the Committee's activities will be awaited with considerable interest, not only by those within the industry, but by every section of trade dependent to a varying degree on iron and steel in their many forms.

Tees Increase Shipments of Steel.

Although August is a holiday month, returns of iron and steel shipped from the Tees last month equal those of July and indicate that the volume of trade has been maintained. The total clearances last month were 35,392 tons, compared with 35,991 tons in the previous month. The outstanding feature in the returns is that the shipments of steel to destinations overseas are the highest recorded this year. The coastwise clearances are down on July, but there has been a slight advance in the tonnage of pig iron shipped, both coastwise and abroad. Despatches of pig iron, however, remain disappointingly small. Last month's amounted to no more than 7,296 tons.

Manufactured steel shipments reached 27,407 tons, of which 18,633 tons were cleared for foreign destinations, including 8,230 tons to Russia. These deliveries consist mainly of plates and a certain amount of blast-furnace equipment.

Mineral Production of United States in 1931

The approximate total value of mineral products in the United States in 1931 was $3,180,000,000, or a drop of 33% from the total value of mineral products in 1930, according to the statistical and economic survey published by the United States Bureau of Mines. Declines in values, accounted for both by lower unit prices and by the falling off in output of nearly all mineral products, are principally explained by the world depression that affected virtually all lines of industrial activity. The total value of metallic products in 1931 decreased 42 per cent, as compared with 1930. Notable decreases in total values, ranging from 44 to 54 per cent, were recorded for copper, iron, silver, lead, and zinc, but the value of gold production increased 5 per cent. The total value of non-metallic mineral products in 1931 decreased 31% from the preceding year, also the mineral fuels declined 32%. The following figures give the approximate total value of metallic mineral products and non-metallic mineral products other than fuel and of mineral fuels produced in the United States in 1931 :—

Metallic	$567,200,000
Non-metallic (other than fuels)	719,700,000
Mineral fuels	1,885,800,000
Unspecified	7,300,000
Total	$3,180,000,000

New Soviet Metallurgical Works at Tula.

A new metallurgical works are being built about ten kilometres from Tula. It is to be one of the biggest in the Soviet Union. It will have seven blast furnaces of an annual capacity of 1,350,000 tons of pig iron, a coke and chemical factory, casting shops estimated for dealing with a capacity of 850,000 tons of pig iron, a pipe plant, and an electric power-station of 50,000-kw. capacity. This will involve the building of a new town around the works to accommodate about 35,000 inhabitants. Plans are prepared for blowing of the first blast furnace on January 1, 1933, and the second on April 1, 1933.

Soviet Output of Rolled Iron.

During the first six months of 1932 the output of rolled iron in the Soviet Union equalled 2,224 tons, as against 1,917,000 tons in the corresponding period of 1931. In the year 1913 the total production of rolled iron was 3·5 million tons ; in 1929 it was 3·9 million tons, and in 1931, 4·1 million tons.

Some Contracts.

The British Thomson-Houston Co., Ltd., Rugby, has just received an order from Associated Electrical Industries (India), Ltd., for a large synchronous motor to drive a continuous sheet bar and billet rolling mill at the Jamshedpur Works, India, of the Tata Iron and Steel Co. The motor, which is of the totally enclosed type, with closed-circuit air cooling, will be rated at 7,500 h.p., 6,300/3,150 volts, 50 cycles, 0·8 leading power factor, 93·8 r.p.m., and will be able to take peak loads of 18,750 h.p. In addition, the B.T.H. Co. is also supplying the automatic control gear for starting, reversing, and emergency stopping.

The motor will be the largest machine of its kind ever built in Great Britain, the diameter being 26 ft., with a shaft no less than 2 ft. diameter.

Within 24 hours of the order being received the stator plates were being flame-cut in the B.T.H. Rugby works as a preliminary to the building-up of the frame. In fact, the facilities which the B.T.H. Co. has at its disposal for turning out such a motor quickly were of important assistance in securing the order against world-wide competition.

The Tees-side Bridge and Engineering Co. has secured orders for two spans to form a bridge over the Tugela River, South Africa, and a steel suspension bridge over the Potaro River, British Guiana, and for the construction of large sheds for the London Electric Railway.

Messrs. Charles Hill and Sons, Bristol, have received a contract for the building of two hoppers from the Great Western Railway. The vessels will be 175 ft. long, with a beam of 34 ft. and depth of 15 ft. Their mud-carrying capacity will be 950 tons, and they will be fitted with triple-expansion screw engines, supplied by Messrs. Plenty and Co., of Newbury. They are to be used in connection with dredging operations at Cardiff docks.

W. G. Bagnall, Ltd., Stafford, have received orders for ten locomotive boilers for the Eastern Bengal State Railway, and nine for the North Western Railway in India.

Rushton and Hornsby, Lincoln, have secured an order for five oil engines and accessory plant to be installed in the new power-station of the Basra Port directorate.

Messrs. Blackstone and Co., Ltd., of Stamford, Lincolnshire, have received an order for the supply of sludge-pumping equipment for the Gravesend sewage disposal works. The order includes 11 sets of electrically driven Blackstone "unchokeable" sludge pumps, controlled by both automatic and hand-operated starters. The complete contract is estimated to be valued at about £3,500.

Furness Shipbuilding Co., Ltd., of Haverton-on-Tees, have received an order for a sliding caisson to be used in connection with the graving dock being constructed at Millbrook, Southampton, for the Southern Railway Co. The caisson is of the double-faced type, and will be 142 ft. in length, 29 ft. 6 in. in width, and 58 ft. 6 in. in depth. It will be constructed in the shipbuilding yard, launched, and subsequently towed to Southampton. About 1,500 tons of steel will be involved in its construction.

Messrs. John Baker and Bessemer, Ltd, of Rotherham, have received an order for wheels and axles for use on the Danish State Railways. These wheels and axles are for use on the new motor-coaches in connection with the electrification of the Danish State Railways, for which British contractors recently secured an order for electric train equipment to cost £300,000.

Sir Wm. Arrol and Co., Ltd., of Glasgow, have received an order for two 50-ton four-motor overhead electric travelling cranes required for the erecting shop at the London and North Eastern Railway locomotive works, Cowlairs, Glasgow.

Guy Motors, Ltd., Wolverhampton, have been awarded a repeat order by the War Office for 3/5-ton rigid six-wheeled vehicles, designed to carry 3-ton loads over soft ground and 5-ton loads on hard roads. Each vehicle will be fitted with an auxiliary gearbox, giving eight speeds forward and two reverse, so as to enable a fully laden vehicle to negotiate gradients of 1 in 3 over soft ground.

Messrs. Head, Wrightson and Co., Ltd., have received an order from the London and North Eastern Railway Co. for an electrically operated telescopic type anti-coalbreaker for use at North Blyth staithes.

The Ismailia Valve Co., of Victoria Street, London, S.W. 1, has secured a contract from the Leamington Corporation for 33-in., 30-in., and 24-in. watertight tidal valves.

Vickers-Armstrong, Ltd., of Barrow-in-Furness, have been awarded the contract by the Admiralty for the 5,450-ton cruiser *Ajax*, which includes both hull and machinery, together with the armaments.

MARKET PRICES

ALUMINIUM.

98/99% Purity	£95 0 0

ANTIMONY.

English £35 0 0 to	£42 10 0
Chinese	25 0 0
Crude	16 0 0

BRASS.

Solid Drawn Tubes	lb.	9d.
Brazed Tubes	lb.	11d.
Rods Drawn	,,	8d.
Wire	,,	7⅞d.
*Extruded Brass Bars	,,	4½d.

COPPER.

Standard Cash		£38 0 0
Electrolytic		40 0 0
Best Selected		39 10 0
Tough		39 0 0
Sheets		68 0 0
Wire Bars		40 0 0
Ingot Bars		40 0 0
Solid Drawn Tubes	lb.	10d.
Brazed Tubes	,,	10d.

FERRO ALLOYS.

‡Tungsten Metal Powder	lb.	0 2 0
‡Ferro Tungsten	,,	0 1 9
Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up.		
NOMINAL 2-4% Carbon, scale 12/- per unit	ton	35 15 0
NOMINAL 4-6% Carbon, scale 8/- per unit	,,	26 17 6
NOMINAL 6-8% Carbon, scale 8/- per unit	,,	24 10 0
NOMINAL 8-10% Carbon, scale 8/- per unit	,,	23 15 0
§Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steel-work. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 11/6 per unit	,,	37 17 6
Guar. max. 1% Carbon, scale 14/- per unit	,,	41 10 0
§Guar. max. 0.7% Carbon, scale 15/- per unit	,,	46 0 0
‡Manganese Metal 96-98% Mn.	lb.	0 1 4
‡Metallic Chromium	,,	0 2 8
§Ferro-Vanadium 25-50%	,,	0 12 8
§Spiegel, 18-20%	ton	6 17 6
Ferro Silicon—		
Basis 10%, scale 3/- per unit	ton	5 17 6
20/30% basis 25%, scale 3/6 per unit	,,	8 10 0
45/50% basis 45%, scale 5/- per unit	,,	13 15 0
70/80% basis 75%, scale 7/- per unit	,,	18 17 6
90/95% basis 90%, scale 10/- per unit	,,	30 0 0
§Silico Manganese 65/75% Mn., basis 65% Mn.	,,	12 10 0
§Ferro-Carbon Titanium, 15/18% Ti	lb.	0 0 6
Ferro Phosphorus, 20-25%	ton	22 2 6

FUELS.

Foundry Coke—		
S. Wales	£1 0 0 to	1 2 0
Sheffield Export	—	—
Durham	1 1 0 to	1 4 0
Furnace Coke—		
Sheffield	0 13 6 to	0 15 6
S. Wales	—	0 16 0
Durham	—	0 12 0

GUN METAL.

*Admiralty Gunmetal Ingots (88 : 10 : 2)		£50 0 0
*Commercial Ingots		41 10 0
*Gunmetal Bars, Tank brand, 1 in. dia. and upwards	lb.	0 0 9
*Cored Bars	,,	0 0 11

LEAD.

Soft Foreign	£14 1 0
English	16 0 0

MANUFACTURED IRON.

Scotland—	
Crown Bars, Best	£10 5 0
N.E. Coast—	
Rivets	11 0 0
Best Bars	10 10 0
Common Bars	10 0 0
Lancashire—	
Crown Bars	9 15 0
Hoops £10 10 0 to	12 0 0
Midlands—	
Crown Bars £9 15 0 to	10 0 0
Marked Bars	12 0 0
Unmarked Bars	—
Nut and Bolt Bars £8 7 6 to	8 12 6
Gas Strip	10 12 6
S. Yorks.—	
Best Bars	10 10 0
Hoops. .Hoops £10 10 0 to	12 0 0

PHOSPHOR BRONZE.

*Bars, " Tank " brand, 1 in. dia. and upwards—Solid	lb.	9d.
*Cored Bars	,,	11d.
†Strip	,,	10¾d.
†Sheet to 10 W.G.	,,	11¾d.
†Wire	,,	1/-
†Rods	,,	11d.
†Tubes	,,	1/4
†Castings	,,	1/1½
†10% Phos. Cop. £30 above B.S.		
†15% Phos. Cop. £35 above B.S.		
†Phos. Tin (5%) £30 above English Ingots.		

PIG IRON.

Scotland—	
Hematite M/Nos.	£3 8 6
Foundry No. 1	3 12 0
,, No. 3	3 9 6
N.E. Coast—	
Hematite No. 1	3 4 0
Foundry No. 1	3 1 0
,, No. 3	2 18 6
,, No. 4	2 17 6
Cleveland—	
Foundry No. 3	2 18 6
,, No. 4	2 17 6
Silicon Iron	3 1 0
Forge No. 4	2 17 0
N.W. Coast—	
Hematite	3 14 6
Midlands—	
N. Staffs Forge No. 4	3 1 0
,, Foundry No. 3	3 6 0
Northants—	
Forge No. 4	2 17 6
Foundry No. 3	3 2 6
Derbyshire Forge	3 1 0
,, Foundry No. 3	3 6 0
West Coast Hematite	3 6 0
East ,, ,,	3 3 6

SWEDISH CHARCOAL IRON AND STEEL.

Pig Iron	94 KRONOR.
Billets	£12 13 6 to £16 0 0
Wire Rods	£14 12 0 ,, £17 12 6
Rolled Bars (dead soft)	£10 4 0 ,, £11 11 0
Rolled Charcoal Iron Bars	— £16 0 0

All per English ton, f.o.b. Gothenburg.

SCRAP METAL.

Copper Clean	£27 0 0
,, Braziery	24 0 0
,, Wire	—
Brass	17 0 0
Gun Metal	18 0 0
Zinc	8 0 0
Aluminium Cuttings	74 0 0
Lead	11 0 0
Heavy Steel—	
S. Wales	1 18 6
Scotland	1 12 6
Cleveland	1 15 0
Cast Iron—	
Midlands	1 15 0
S. Wales	2 2 0
Cleveland	1 16 0
Steel Turnings—	
Cleveland	1 8 0
Midlands	0 19 0
Cast Iron Borings—	
Cleveland	1 2 6
Scotland	1 10 0

SPELTER.

G.O.B. Official	—
Hard	£12 10 0
English	17 10 0
India	15 5 0
Re-melted	15 5 0

STEEL.

Ship, Bridge, and Tank Plates—	
Scotland	£8 15 0
North-East Coast	8 15 0
Midlands	8 17 6
Boiler Plates (Land), Scotland	9 0 0
,, ,, (Marine) ,,	..
,, ,, (Land), N.E. Coast	10 0 0
,, ,, (Marine) ,,	10 10 0
Angles, Scotland	8 7 6
,, North-East Coast	8 7 6
,, Midlands	8 7 6
Joists	8 15 0
Heavy Rails	8 10 0
Fishplates	12 0 0
Light Rails £8 10 0 to	8 15 0
Sheffield—	
Siemens Acid Billets	9 2 6
Hard Basic .. £8 2 6 and	8 12 6
Medium Basic. .£6 12 6 and	7 2 6
Soft Basic	6 0 0
Hoops £9 10 0 to	9 15 0
Manchester—	
Hoops £9 0 0 to	10 0 0
Scotland, Sheets 24 B.G.	10 5 0

HIGH SPEED TOOL STEEL.

Finished Bars 14% Tungsten.	lb.	2/-
Finished Bars 18% Tungsten.	lb.	2/9
Extras		
Round and Squares, ½ in. to ¼ in.	,,	3d.
Under ¼ in. to $\frac{1}{8}$ in.	,,	1/-
Round and Squares 3 in.	,,	4d.
Flats under 1 in. × ¼ in.	,,	3d.
,, ,, ¼ in. × ¼ in.	,,	1/-

TIN.

Standard Cash	£157 15 0
English	159 10 0
Australian	161 5 0
Eastern	164 10 0
Tin Plates I.C. 20 × 14 box	15/- 15/6
Block Tin (Cash)	147 10 0

ZINC.

English Sheets	£23 0 0
Rods	27 0 0
Battery Plates	—

* McKechnie Brothers, Ltd., quoted Sept. 8. † C. Clifford & Son, Ltd., quoted Sept. 8. ‡ Murex Limited, quoted Sept. 8

Subject to Market fluctuations. Buyers are advised to send inquiries for current prices.

§ Prices quoted Sept. 8, ex warehouse.